DOCUMENT RESUME

ED 422 163 SE 061 669

AUTHOR	Fortner, Rosanne W., Ed.; Mayer, Victor J., Ed.
TITLE	Learning about the Earth as a System. International Conference on Geoscience Education Conference Proceedings (2nd, Hilo, HI, July 28-31, 1997).
INSTITUTION	Ohio State Univ., Columbus.
PUB DATE	1998-00-00
NOTE	190p.
PUB TYPE	Collected Works - Proceedings (021)
EDRS PRICE	MF01/PC08 Plus Postage.
DESCRIPTORS	*Earth Science; *Educational Strategies; Elementary Secondary Education; Geology; Higher Education; Learning Strategies; Public Policy; Science and Society; *Science Curriculum; *Science Education

ABSTRACT

Learning about the earth as a system was the focus of the 1997 International Conference on Geoscience Education. This proceedings contains details on the organization of the conference as well as five general sessions by various participants. The interactive poster sessions are organized according to three themes: (1) Earth Systems/Science Programs; (2) Earth Systems/Science Instruction; and (3) Public Information, Research, and Innovation. Addresses related to the conferring of four lifetime service awards are also included along with conference highlights, participants' evaluation of the conference, participant addresses, and an index to program contributors. (DDR)

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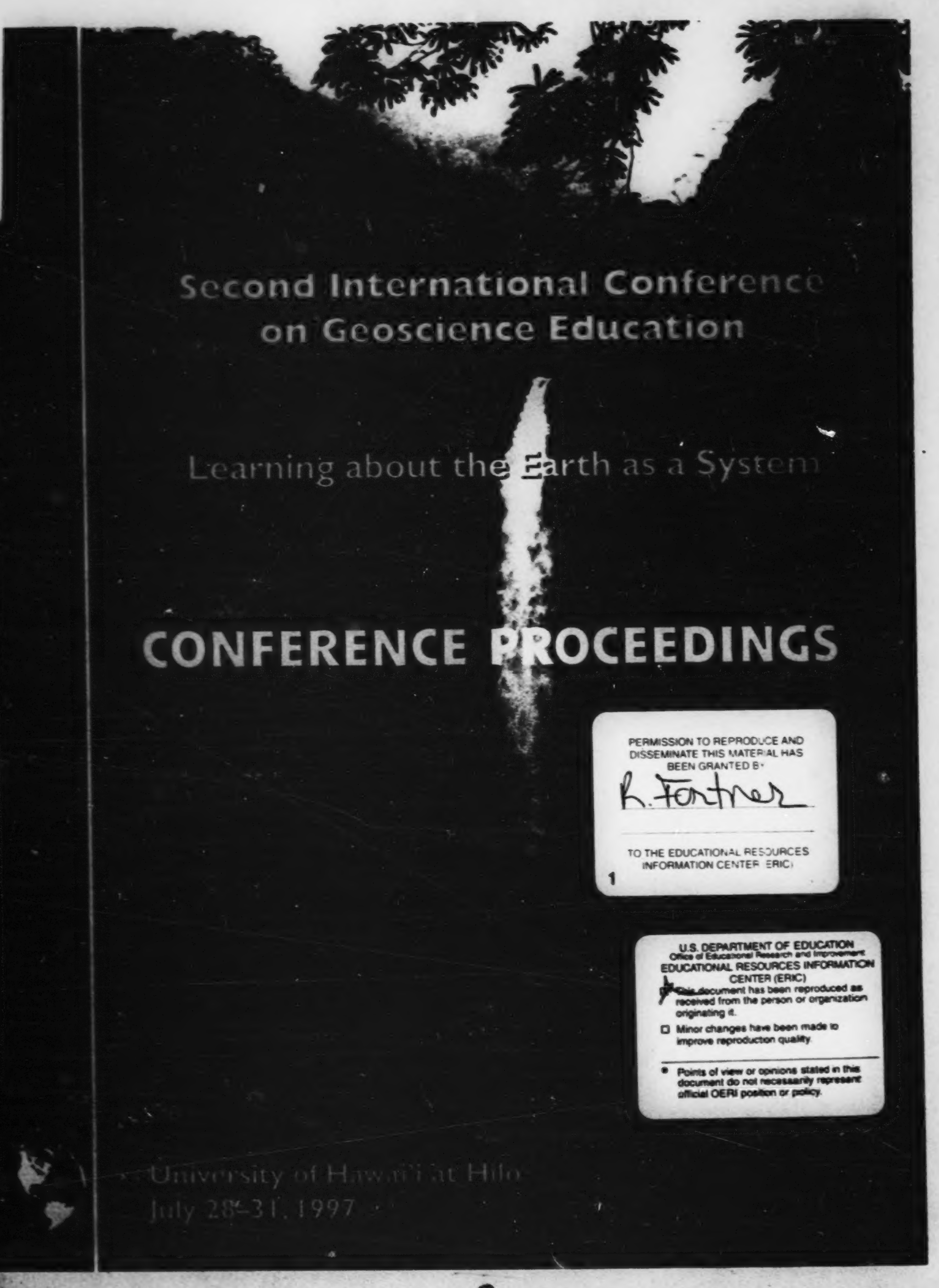

Second International Conference on Geoscience Education

Learning about the Earth as a System

CONFERENCE PROCEEDINGS

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University of Hawai'i at Hilo
July 28-31, 1997

Second International Conference on Geoscience Education

Learning about the Earth as a System

CONFERENCE PROCEEDINGS

University of Hawai'i at Hilo
July 28–31, 1997

IN MEMORY OF

DR. EDWIN L. SHAY

1938 – 1998

EARTH SYSTEMS EDUCATOR

INSPIRING TEACHER, COACH, MENTOR, LEARNER AND FRIEND

Support for production and distribution of Proceedings provided by

- National Science Foundation, Directorate for Education and Human Resources (U.S.)
- National Aeronautics and Space Administration, Mission to Planet Earth program (U.S.)
- Conference registrations
- The Ohio State University, School of Natural Resources and Office of Applied Communications
- The Alphyl Memorial Endowment Fund of The Ohio State University, a fund established in honor of Victor C. and Phyllis C. Mayer.

Rosanne W. Fortner and Victor J. Mayer, Editors

PAST AND FUTURE CONFERENCES

First International Conference on Geoscience Education and Training, April 1993, Southampton, England. Proceedings edited by D.A.V. Stow and G.H.J. McCall and published by A.A. Balkema, Publishers, Rotterdam, The Netherlands.

The Third International Conference will be held in Sydney, Australia,17–20 January 2000. Advance information will be available from Gary Lewis (glewis@agso.gov.au) at the address in the back of this volume.

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Learning about the Earth as a System

The Second International Conference on Geoscience Education was held July 26-August 2, 1997, in the beautiful and dynamic Hawai'ian Islands. This conference was an outgrowth of the First International Conference on Geoscience Education and Training, held in Southampton, England, in April 1993. The primary focus of the first conference was the state of geoscience education throughout the world. At the end of that meeting it was decided to convene a Second International Conference to be held in the United States, with a focus on one or more specific issues.

The theme of our second conference, "Learning about the Earth as a System," was chosen because it emphasizes the importance of reexamining the teaching and learning of traditional Earth Science in the context of the many environmental issues facing the planet and the advent of remarkable technology that can assist in data management and science instruction. If issues of sustainable development and use of resources are to be effectively addressed, it is imperative that students at all grade levels and from all cultures have an understanding of how the Earth works. Further, because many of these issues transcend national boundaries, students must understand how people in various cultural settings interact with the environment and with each other.

A consensus is developing among many educators, from early childhood to university level, that the traditional approach to Earth Science education is falling short of what will be required for citizenship and professional success in the next millennium. There must be a change in *what* we have students study and *how* that information is presented to them. We can no longer allow Earth Science to be taught as a collection of facts in separate units of geology, meteorology, astronomy and oceanography.

The term "Earth System" came into prominent use after publication of the so-called Bretherton report in 1986 by the National Aeronautics and Space Administration of the U.S. *Earth System Science: A program for global change* was an outline and rationale for establishing an interdisciplinary data collection and interpretation program using satellites as a remote platform for observing global changes. The Earth System Science proposed in the report, a relatively new approach to understanding how the Earth works, provides a way to integrate Earth Science educational programs. Earth System Science regards the Earth as a system within the Solar System and the sub-systems of Earth–the solid Earth, atmosphere, hydrosphere and biosphere–as separate but interacting systems.

Further, from within and outside the educational system there is a growing consensus that teaching strategies should focus on (1) students constructing knowledge through inquiry, (2) addressing the varying learning styles of all students, (3) promoting learning through cooperative group activity rather than competition, and (4) effective use of technology.

The Earth System approach to Earth Science education, and complementary changes in instruction and assessment, are enjoying growing acceptance around the world. It was for this reason that we convened this international conference with its goal of sharing with all participants the advances in and prospects for "Learning about the Earth as a System."

Mahalo (thank you) for your interest in this Proceedings volume! Please visit the conference Internet site throughout 1998 for additional photographs and information (*http://www.ag.ohio-state.edu/~earthsys/conindex.html*).

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Conference Co-Conveners

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Conference Sponsorship and Support

The conference was sponsored by The Coalition for Earth Science Education, and the Commission on Geoscience Education and Training of the International Union of Geological Science and Association of Geoscientists for International Development.

Support for the conference came from numerous sources, including the American Geophysical Union, the American Geological Institute, National Association of Geoscience Teachers, National Earth Science Teachers Association, The Ohio State University, the University of South Carolina, the Weizmann Institute (Israel), the University of Hawai'i—Manoa and Hilo, and Hyogo University of Teacher Education (Japan).

Three government agencies from the United States provided very substantial support for the conference:

- The National Science Foundation, Education and Human Resources Directorate, provided partial support for 18 secondary school science teachers and nine college earth science teachers to participate in the conference. In addition, support was provided for conference speakers and the editing and printing of the conference proceedings. The grant was to the Center for Science Education of the University of South Carolina with John Carpenter as Principal Investigator.
- The National Aeronautics and Space Administration, Mission to Planet Earth Program, provided support for the pre-conference field trips, the conference workshops, speakers, and administrative activities of the program committee including the printing of the conference program. The grant was to The School of Teaching and Learning of The Ohio State University with Victor Mayer as Principal Investigator.
- The United States Geological Survey provided personnel and financial support for the conference field trip. This was under the supervision of Laure Wallace.

EXECUTIVE SUMMARY

Approaches, Issues and Potential for Learning about the Earth as a System

Serious concerns have been raised from within the community of Earth Science scholars and educators that the subject matter of earth has been diluted, subsumed in other subjects, or worst of all, ignored. At a time when it is becoming apparent that ignorance of Earth processes may be committing the planet to unforeseeable and perhaps unalterable changes, it is imperative that more people become aware of how the Earth works and how human activity can influence the functions of Earth systems. If less Earth science is being taught, fewer students will be captured by its excitement, and fewer Earth scientists will be available to monitor the vital functions and alert us to changes in those systems. With less knowledge of science, we cannot enlighten policy or encourage further study. The cycle of ignorance could affect not only interdisciplinary education but critical science and policy.

What is the status of the science of Earth? To what extent is it being taught, and how? What information can stakeholders use to encourage more and better education about the Earth, through schools, laboratories, public information programs, and networks? These questions and others were addressed at the Second International Conference on Geoscience Education, held in July 1997 at the University of Hawai'i-Hilo.

Sources of summary information.

Contributions of Invited Speakers. Five individuals were identified by the conference program committee to represent modern interdisciplinary science of the Earth system, educational innovation, and the relationship of knowledge of the Earth to human culture. Complete texts of their talks are featured in the Proceedings volume, but key concepts are highlighted here. In addition, four individuals were honored for their contributions over their lifetime of service to geoscience education. Like the other selected speakers, this group exemplified what the conference organizers felt were the salient aspects of doing sound interdisciplinary science and educating many about the Earth system. Their stories of how science and education have changed over the period of their careers, and their hopes for the future of Earth systems education, offer leadership lessons for all.

Participant contributions. An innovative format was instituted for presenters responding to the call for papers. "Interactive poster sessions" allowed for sets of poster presentations on a common topic to be followed by discussion groups for considering the international aspects and the similarities and differences of approach offered by the various contributors to the topic. As such, the conference participants took away more than just a set of notes on individual sessions they selectively attended. In addition, they participated in collegial discussions for analysis and synthesis of ideas. Session moderators collected and summarized these ideas at the end of each poster set, and their collective results offer an excellent overview of

- prevailing approaches to the science of the Earth system,
- innovative means of teaching about interdisciplinary aspects of Earth, and
- lessons for those who would lead efforts for "learning about the Earth as a system."

Conference Outcomes I: Earth as a System

Rationale for Earth System Science. The conference focused on "Learning about the Earth as a System," a theme chosen because of the importance of focusing on how all parts of the Earth (hydrosphere, atmosphere, lithosphere, and biosphere) are interconnected, and how forces that impact one component also generate responses in the others. The National Aeronautics and Space Administration (NASA), the U.S. agency that uses Earth System Science to guide its Earth monitoring efforts, began using the term as the result of a committee report which recognized "important connections among the components of the planet Earth and thus emphasized the essential unity of global processes, which are only now beginning to be studied systematically" (Earth System Science Committee, 1986). The goal of Earth System Science, as defined by the committee, is "to obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales." The choice of a conference theme that focused on Earth as a system was based on the need to make more geoscience scholars and educators aware of the systems concepts and their appropriateness for the Earth science professions.

Featured speakers Thomas Schroeder, chair of the Meteorology Department at the University of Hawai'i at Manoa, and Ellen Mosley Thompson of the Byrd Polar Research Center at The Ohio State University, demonstrated what Earth system science was through their use of interdisciplinary sciences as the means of explaining local and global features of Earth. Schroeder used the patterns of weather in the Hawai'ian Islands, which are subject to the Trade Winds, to demonstrate how land shape (topography) and geographic orientation influence local wind and rainfall patterns that result in widely varying climate zones on single islands and across the island chain. He described how the biosphere of the islands is affected by land, air and water as well, noting for example that a spider living in the virtual desert at the top of Mauna Loa is able to get food because wind patterns loft insects and moisture up from lower elevations. Thompson introduced all the sciences of the Earth system in her discussion of how global climate changes are studied through ice cores collected at high elevations and examined for molecules and dust particles trapped in them at the time of their formation. The same ice cores assist in analysis of rates of change as well as current status of the cryosphere, an indicator of changes in other global systems such as the atmosphere. Both scientists use an interdisciplinary approach to pursue answers to important questions being asked in their fields. Their presentations demonstrated how collaboration with colleagues extends the impacts of science by crossing disciplines and drawing on the relevant tools and understandings from other research. While both scientists have made science their career focus, both are also faculty at the university level, helping others learn about the Earth as a system.

Another invited speaker offered a unique perspective on systems aspects and the science of Earth. Kepa Maly was raised by a Hawai'ian family and taught the principles of living with the land and honoring its spirit and power. In a sensitive presentation he showed how knowledge of the Earth system relates to human life, and how various cultures have interpreted and used the Earth in different ways. His analogies of Earth names for human positions demonstrated that knowing the Earth helps to know the culture as well. For example, the Hawai'ian name for an elder in the community is the same as the word for "the source of the water," indicating not only that the elders are vital to existence, but that water is highly valued as a heritage.

Among the awardees for lifetime service are individuals who are credible Earth scientists as well as notable educators. Victor J. Mayer, for instance, continues in retirement to assist teaching a graduate seminar in the History of Geology for the Department of Geosciences at Ohio State, and his personal interest in current topics of the changing Earth system has enabled him to bring scientists on the leading edge of the disciplines into contact with teachers in workshops. His view of global science literacy is one of personal, culturally shaped Earth systems understanding, based on strong science and on commitment to environmental quality. In other presentations and discussions during the conference it became evident that the value of Earth system understanding was being put forward as a major component if not the basis of science literacy.

Another awardee, Emmanuel Mazor of Israel, offered a perspective intended to explain why many people find it difficult to grasp some concepts key to Earth system science. Mazor pointed out that theory is most commonly presented as a "given," without the observations on which the theory was originally based. Scientific thinking, on the other hand, begins with observations which contribute to working hypotheses that may become the basis of theory. He provided several science examples that are difficult for students to grasp, then offered some suggestions for how locally observed phenomena can make the theories meaningful by drawing on students' experience with the natural world.

Interpretation of the Earth system science theme was evident in a number of the poster presentations, in which the content of geoscience courses for various countries was compared and naive conceptions about Earth system topics were explored. It was noted, for instance, from studies in Israel, that students are not correctly interpreting the global carbon cycle or even the hydrologic cycle. Misconceptions about geologic time are common worldwide, and the social implications of this for developing a time/space understanding of human impacts and current rates of change are very serious. Learning about global environmental change issues was seen to be a means of making Earth systems science relevant and also to demonstrate the strength of the science research base.

A number of opportunities for interpreting the Earth systems by modeling and other technologies were explored in the conference. Technology uses were demonstrated in the form of Geographic Information Systems, satellite image data collection and interpretation, student conceptual models translated into models usable on a desktop computer, computer aided instruction in advanced structural geology, use of remote sensing and multispectral imaging of vegetation in Biosphere 2, and using technology to share data across various collection groups and countries. A special workshop on visualization of data was conducted to demonstrate how integration of the sciences and human factors of the environment could be portrayed electronically for better understanding of relationships.

Implementation. When scientists and educators discussed the science of the Earth system, it became clear that they were concerned about how the disciplines are divided in their method of doing research, for this influences how students are taught in lecture and lab. Indeed, it is the integration of the sciences that is a primary constraint to their desired level of implementation. Teachers at all levels must be specifically trained in HOW to integrate the disciplines, and WHY students should be able to do this instead of memorizing facts for possible use later. The science might be revisited each year in the school curriculum, with integration with other subjects occurring vertically across the grades. Most countries still look horizontally across a year's work, however, and see how topics in Earth science should be sequenced within one period of study time. In some countries the science of the Earth is still a rigorous factual area for study, and teacher education is focused on training strong subject matter specialists; field investigations are the reinforcers for interdisciplinary aspects.

Field experience. Numerous reports of how Earth systems science is implemented included the strength of field experiences, and the conference itself reinforced this. Field trips that are most effective are not those with show-and-tell at the places where the bus can get off the road. A special field trip organized by Laure Wallace of the USGS was planned for all conference participants to tour Hawai'i Volcanoes National Park using an interdisciplinary, systems-oriented format. Instead of simply stopping to explore the traditional marked stops on the road surrounding the active volcanic area, special effort was taken to assure that all Earth subsystems were clearly shown in relation to each other. Devastation Trail, for instance, was staffed by a geologist and a botanist who together demonstrated how the fine volcanic ash had spared some trees and scorched others, how distribution of vegetation followed cracks in the lava, and how aerial roots on some trees captured atmospheric moisture in the absence of moisture from the ground. Lava tubes were explored for their relationship to the plant and animal life of the area, their role in human culture, and their importance in transmitting flowing lava far from its origin, thus increasing the size of the island. An area with active fumaroles was the background for a discussion of island air pollution in the form of "vog," a fog formed with sulfur gases and water vapor, creating acidic conditions and exacerbating human respiratory problems.

A question of fit. Earth sciences are typically the last science to come to mind in science education, and in fact many countries have now placed the Earth sciences into courses of physical geography. Representatives of these countries noted that neither the geography nor the Earth sciences were heavily subscribed by student enrollment. Even in the United States, speaker Rodger Bybee spoke of how some developers of the National Science Education Standards favored putting Earth concepts into Life Science (evolution, for instance), or into Physical Sciences (matter and minerals), and Societal Impacts of Science (global climate change, acid rain, etc.). The very features that make Earth sciences function on a systems model make them vulnerable to recombination and dissolution into unrecognizable forms. Those same features, however, make Earth Systems Science a strong favorite among those who see a need for school science to change to a post-Cold War model, providing an ideal medium for integrating the various sciences in the science curriculum. There is no longer a strategic need for physics and the sciences of war, thus the school curriculum might better focus on strategic means of surviving human impacts on the global environment.

In the U.S., a group of colleges and universities are joining together to develop programs in Earth System Science Education (ESSE) through the Universities' Space Research Association. Each institution has developed an entry-level course in Earth System Science for non-science majors, and a capstone course for seniors that brings together the science disciplines to focus on a global issue such as food supply or global change. The ESSE model appears to have much to offer the scientists in its use of scientific modeling and its determination to cross disciplines in a meaningful way, and much to offer modern educators as well in the techniques and tools used to emulate scientific inquiry. Examples of models of Earth processes and new ways to visualize and interpret data strengthen this kind of modern approach.

Potential and Issues. In shaping the program for the conference, the organizers attempted to model the kinds of Earth system science and educational potential that were being encouraged. Good science was the focus of numerous presentations from a wide variety of countries, and the conference provided fascinating examples of how scientists were reaching toward the theme of Earth as a system. For example, an introduction to crystallography was as artistic as it was scientific; a workshop taught people how to construct simple input-output models of Earth systems; videotape and CD-ROM provided in-depth views of Earth events such as the eruption of Heimaey to the extent that textbooks could not. A number of college programs employing interdisciplinary techniques were described, including field studies, local and regional geoscience features, mine tours, and natural disaster effects mitigation, all as means of making the sciences more relevant to learners and therefore more attractive within the curriculum.

In secondary schools some of the same tools are being used to enliven the curriculum and generate interest in Earth systems. Mapping, image processing and computer simulations appear to be the favored junior high and high school modes of demonstrating how sciences are interrelated. Some schools have the opportunity to integrate other disciplines as well, and teach through language arts, math, music and mythology to capture the attention of those with different learning styles and experiences. Paper cores hanging from the ceiling demonstrated a means of teaching stratigraphic correlation; baking soda in film canisters showed why some volcanoes erupt and others just flow; a plate tectonics teaching supplement and map of "This Dynamic Earth" provide global data for studies of how the planet is changing. Yolanda Alba de Gonzales, a life-time service awardee from Venezuela, provided information on how software and artists' graphics were integrated into secondary teacher workshops and used to generate environmental impact studies based on real situations. Indeed it was notable how frequently Earth system science was introduced or characterized through study of an environmental issue or relationship of human activity.

Research based on such efforts was reported from a number of countries and educational levels. It appears that there are still many misconceptions about the Earth system among students and the public, and that the use of some technologies are being implemented too early. Certain types of technology experiences could be frustrating if they are not limited to students who have reached abstract levels of thinking. Comparative research in several Latin American countries demonstrates that problems within science are common across the cultures, as are problems within education.

Looking ahead. Because of issues of declining enrollment in the geosciences, several presentations dealt with the training of geoscience specialists. A study of the demographics of Earth systems science professions confirms that this is an aging group, yet some scientists are pessimistic that the educational system will be willing to make the changes needed to foster attention to the needs of the professions. Some problems may arise in communication from the profession to the trainers. Job descriptions have been changing dramatically. It is difficult to prepare people for careers when the interdisciplinary nature of the professions is not apparent, and the preparation that follows traditional disciplinary lines is not seen by most as being adequate for current jobs. The need for interdisciplinary training is not even a view shared by all. Some scientists believe strongly that the Earth sciences require special skills and knowledge that would not be acquired in other areas, thus they see a need to keep Earth science students apart from others and use technologies and techniques specific to the Earth disciplines in at least some portion of their professional training.

Thus the primary Earth system science issues emerging from conference discussions and reports can be grouped into three broad categories: interdisciplinary and/in professional training, public Earth systems science literacy, and application of Earth system science to studies of environmental change. The "Scientist" participants (most would claim to be in this group) were actually a group that was already implementing change toward interdisciplinary, systems-oriented research and teaching. Apparently the conference announcements attracted the innovators in the field. If these same people are the opinion leaders in their institutions and countries, educational leaders in Geoscience can make strides toward entering the 21st Century ready for the challenges of a new way of thinking about their subject.

Conference outcomes II: Learning about the Earth

Rationale and Interpretation. If scientists and educators accept that Earth is a system and should be studied in ways that reinforce that notion, what does such learning look like and how does it occur? What will have to happen before such learning is considered "real science"?

The rationale for integrating the sciences around a study of Earth was articulated by several major speakers at the conference. Rodger Bybee of the National Academy of Science spoke to the delegates just after he had spoken at a Global Science Education Standards meeting in Korea. He was enthusiastic about the idea of Earth as a focus for the curriculum and offered guidance for those who would implement changes in their own schools. His admonitions about integrating sciences vertically across grades, not just horizontally through one school year, were received with interest, as were his reminders that changes in curriculum alone would not generate changes in science education; they must be accompanied by changes in systems, programs, professional development, assessment and other factors that are spelled out in the National Science Education Standards (NRC, 1996).

Following up on the idea of world standards was the general feeling that education about the Earth system could serve as the integrating force that would foster global science literacy. Such views are being used in curriculum restructure not only in many U.S. school districts but also in other countries. Comparisons of U.S. science education with that in Japan were described by Yoshisuke Kumano, including how implementation of Earth systems education as a way of integrating and modernizing the Earth science curriculum is accomplished and how teachers respond. In Japan as well as in many other regions, Earth systems education is serving to provide information not only on how the sciences of the Earth are interrelated and relevant to learners, but also how human activities have impacted Earth.

While ESE is not to be equated with environmental education, it is undoubtedly seen by many as a logical place in the curriculum for environmental issues to be explored. The changes in Earth science education documented by David Thompson of the UK, and the atmospheric impacts of human activity demonstrated by Ellen Mosley Thompson of the U.S., both focused on the urgent need for environmental protection based on an understanding of how people affect the Earth system. Certain poster presentations and workshops focused on environmental issues as well, providing examples of board games, watershed protection, time-series satellite images for monitoring Earth changes, and the like. It was clear that environmental sciences are emerging as an important component of instruction about the Earth system, and Earth systems education with its intentional integration of subjects offers a pedagogically sound means of teaching about complex environmental interactions.

Implementation. At the secondary school level (middle and high schools), a great range of instructional techniques and tools are being brought into the teaching of sciences of the Earth. Schools in the U.S. are becoming aware that Earth and Space Sciences have a separate set of National Standards, and this legitimizes the subject, providing a new opportunity to pay attention to implementing. Some effective tools that were demonstrated and evaluated at the conference were technology based, in which students can learn to use the same techniques as scientists, and even share their data with scientists as in the GLOBE program. Distance learning technologies enable rural and remote students to participate, and more teachers to learn how these tools work. Networks of students using computers to share information are becoming an exciting way to introduce how science grows through collaboration and exploration of interesting questions among peers.

Presentations and discussions also considered ways to teach, habits of mind and modes of working. Cooperative learning is growing in importance among secondary schools, and students are learning from this experience that they can succeed if they take responsibility for their own learning. Some colleges are experimenting with peer mentoring and cooperative learning as well, but they find the older the students are when these techniques are implemented, the less enthusiastic the students are to try them. They have learned to trust the teacher and their own perception of what the teacher wants, so new learning methods that depend on others are difficult to accept until some personal success is felt within those methods. Another technique in this category is guided discovery, in which student groups are challenged to figure out a problem or situation by collecting and analyzing information and making group decisions.

Issues of pedagogy and practice. Teachers from all grade levels were present to tell their experiences, and many noted similar constraints and boundaries: students are seen as wary of science in general, reductionist learning styles have been reinforced throughout their schooling, and teachers have difficulty teaching in a systems approach because they were not trained that way. Teachers would like to have "kits and cookbooks," the scientists claim, and the teachers acknowledge that until their own professional training can effect changes in the workforce, those crutches may be the only way some teachers can take the first steps to integration.

The challenge must be given to colleges and universities first. Improving college teaching will go far to improve precollege teaching. An excellent example of how college teaching can work is provided by a group of U.S. institutions that have joined minds and other resources for Earth Systems Science Education. The UK is instituting a program for licensing college teachers, not just to assure that they have strong subject matter (their PhD did that) but to assure they can teach! Good examples are the best teachers. Academics who do research should be rewarded for interdisciplinary activity, not chastised or seen as renegades in their discipline, as many are now. Discipline bigotry must be overcome. Emerging disciplines and those that blend science with social issues deserve to be recognized for what they offer the curriculum. Many good college teachers also prefer to do their research instead of teach, often because the reward structure favors research. Academics who teach well should also be rewarded, and it is these types of people who should be in the position of providing professional development for teachers.

For teacher education, NASA's Classroom of the Future offers a course in Earth systems education, taught via the Internet. Other projects facilitated by national funding sources or professional organizations also enhance the systems thinking and provide teachers with ideas and tools for teaching about the Earth system. At the conference, teachers were present who had participated in the Maury Project, Project IMAGE, ESSTEP (Earth and Space Science Technological Education Project), Program for Leadership in Earth Systems Education (PLESE), Project QUEST, Project Skymath, Tropical Rain Forests Forever, From Pebbles to Moon Rocks, GLOBE, and EPIcenter. Many of the projects not only provide support for continuing education, but also facilitate educational change by providing release time for teachers to develop materials or work together to plan collective projects. The range of opportunities is growing, and many teachers learned of new possibilities they will now explore. The importance of professional societies and funded national projects as means of teacher enhancement was clear to those from outside the U.S. They are interested in developing such collaborations in their own countries and found numerous models to emulate.

Lessons From the International Conference

Conference delegates from 27 countries joined into the discussions of education issues and science issues throughout the conference. It quickly became clear in yet another instance that ours is a small world. Concerns are essentially the same worldwide, especially in academia with its research versus teaching dichotomy and its disciplinary barriers. The range of innovative programs presented from countries outside the U.S. was a source of numerous productive conversations, and delegates were overheard planning international collaborations on papers and projects in the near future.

It is difficult to summarize what the real outcomes of a conference such as this might be. Participants come with varying agendas and are bound by a full range of what can be accomplished in their situations versus what cannot. Nevertheless, this particular conference offered more than the usual means of evaluating its outcomes and gauging the extent of what might be the next steps others are willing to take. As a conference with an educational and scientific mission that was fairly well defined, we expect that the Second International Conference on Geoscience Education sent its delegates out with evidence to say:

The Earth is a system; Earth science is not bound by a single discipline.

Earth is an appropriate focus for relevant science learning.

Earth system science helps people understand global environmental change.

Technology useful to my teaching is available.

Field studies are great integrators.

Research has some useful lessons for my teaching.

My situation deals with issues similar to those of others.

I am not alone.

References

Earth Systems Science Committee, 1986. *Earth System Science: A Program for Global Change.* Washington, DC: National Aeronautics and Space Administration.

National Research Council, 1996. *National Science Education Standards.* Washington, DC: National Academy of Science.

Pre-Conference Field Trips

The basic conference theme was carried out through special pre-conference field trips on the island of Oahu. Participants learned about Hawai'ian Earth processes and the results of human interventions in those processes.

Saturday, July 26: Earth Systems Interactions

This all day field trip was designed for both middle school and high school earth science teachers and college/university teachers of geoscience courses. Participants examined the evidence left by interactions between volcanism, the biosphere, ocean, and atmosphere. The effects of atmospheric changes over time were addressed through the examination of sand deposits, abandoned shore lines and other features. Field trip leaders were E. Barbara Klemm, Department of Teacher Education and Curriculum Studies, The University of Hawai'i - Manoa, and Martha Sykes, Hawai'i Institute of Geophysics and Planetology.

Sunday, July 27: Global Change Evidence at Kaena Point

This was a half-day long inquiry-based field trip especially designed for Introductory Geoscience college instructors. Participants examined evidence for global change in coral reef deposits that parallel modern volcanic deposits. Field trip leader was Martha Sykes, Hawai'i Institute of Geophysics and Planetology.

Workshops

These two-hour special sessions offered hands-on learning opportunities designed to be used by either secondary schools or college and university educators.

College\University Workshops

Innovative Teaching Techniques For More Effective Geoscience Education—Ways to Actively Engage Students to Improve Learning.

Barbara Tewksbury, President, National Association of Geology Teachers, Department of Geology, Hamilton College, Clinton, NY 13323

Traditional lecture is a comparatively ineffective way of teaching students. Because most students are passive listeners during lecture, they retain a depressingly small proportion of what is delivered. Retention improves dramatically, however, when students are actively engaged in their own learning. This workshop gave participants specific strategies for actively engaging students in the classroom and provided examples of actual assignments and activities for participants to use as models for creating assignments of their own.

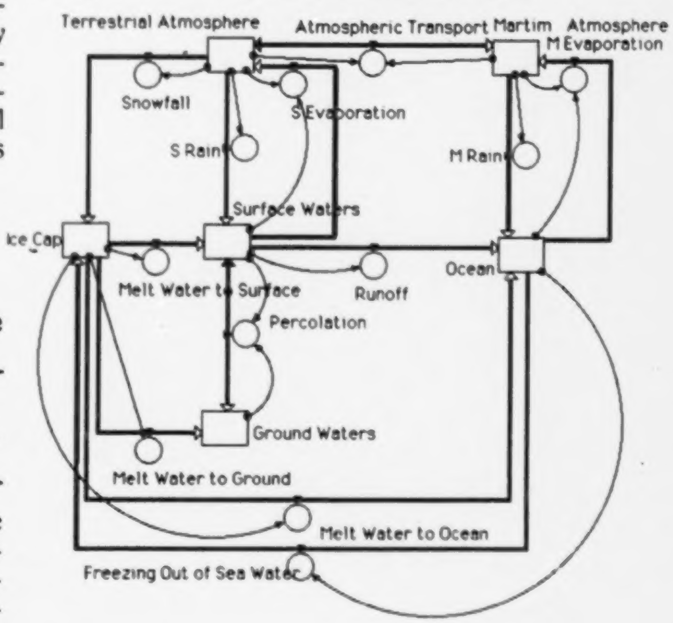
Developing Technology Based Curricula in Earth System Science at the Undergraduate Level.

Sean Cash, School of Natural Resources and Environment, University of Michigan, and John T. Snow, College of Geosciences, The University of Oklahoma

An interdisciplinary introductory course sequence in global change developed at the University of Michigan provides a model for the integration of Internet web-based materials for assessment and large group instruction and the use of modeling and data visualization programs for laboratory experiences. This workshop combined a description of this course sequence with some examples of computer-assisted and web-based tools which can be used in similar undergraduate level courses.

Participants also had the opportunity to explore several models using the STELLA modeling language. Models of various components of the Earth System can be easily constructed and used to explore, in highly simplified form, "how the world works." The layout and operation of a terrestrial energy budget model, a water cycle model, and a carbon cycle model were used with emphasis on the organization of the models as interactive "learning environments." Copies of the models, together with a run time version of STELLA, were provided to allow the participants to actually run the models. More information can be found at *http://www.sprl.umich.edu/GCLI*

A simplified representation of the hydrologic cycle



Earth System Data Analysis and Visualization Tools for Classroom Use.

Daniel C. Edelson, Northwestern University, and Farzad Mahootian, Gonzaga College High School

Earth system science research requires efficient browsing of large volumes of data. The Earth System Visualizer is designed to meet the challenges posed by research-oriented Earth system science courses. WorldWatcher is a visualization and analysis program for global data created specifically for use in education settings. It provides the support that learners require while providing many of the analysis features of scientists' tools. In this workshop, activities demonstrating the use of both of these programs were conducted to acquaint participants with these research and instructional programs and to stimulate discussion regarding their advantages and limitations for use in undergraduate earth systems science courses.

Secondary School Workshops

Sharing the Science of the Earth's System: NASA's Mission to Planet Earth Education Program.

Stephanie Stockman, Science Systems and Applications, Inc.

Mission to Planet Earth (MTPE) is NASA's contribution to developing a vastly improved understanding of the Earth. The unique vantage point of space provides information about the Earth's air, land, water and life—and the interactions among them—that is not available using any other means.

MTPE has education programs which reach K–12 teachers and students as well as faculty and students at the undergraduate and graduate level. These programs emphasize increasing the understanding of the Earth as an integrated system and how natural and human induced change impact the earth's systems on regional and global scales. The education programs also strive to bring up to date technologies and scientific data into the classroom. This workshop provided an overview of MTPE education programs and products. Participants explored MTPE education Internet sites and participated in activities which incorporated MTPE poster and lithograph sets.

Meeting Earth Systems Education Standards Through Technology.

William Hoyt and Ray Tschillard, University of Northern Colorado, and William Slattery, Wright State University, Dayton, OH.

Middle school and high school science teachers are being challenged to have their students meet a variety of state and national standards for science education. In this workshop several approaches and materials were demonstrated that use the Internet on a state or national basis to assist teachers in implementing Earth Systems Education standards. These Earth system activities for elementary (prehistoric animals), middle (plate tectonics and earthquakes), and high school students (the greenhouse effect) are aligned with national and state science education standards.

U.S. Geological Survey Education Resources.

Leslie C. Gordon and Laure G. Wallace, United States Geological Survey

Established by The United States Congress in 1879, the U.S. Geological Survey (USGS) is responsible for providing the Nation with critical geologic, topographic, biologic, and hydrologic information. This information comprises maps, data bases, and reports containing analyses and interpretations of water, energy, mineral, and biological resources, landsurfaces, marine environments, geologic structures, natural hazards, and the dynamic processes of the Earth.

This workshop shared a wide variety of USGS education outreach materials and resources ranging from printed maps, posters, and teacher packets, to real time data on the Internet. Hands on activities about volcanoes, beach sand, coastal erosion, and global change concluded the workshop.

GLOBE—Global Learning and Observations to Benefit the Environment

Stephanie Stockman, Science Systems and Applications, Inc.

The GLOBE program is a hands-on international environmental science and education program. GLOBE links students, teachers, and the scientific research community in an effort to learn more about the environment through student data collection and observation. GLOBE fosters the creation of a worldwide research team comprised of students and teachers in collaboration with scientists for the purpose of generation knowledge of the Earth as an interconnected system. Students from ages five through eighteen years in 3000 schools in more than 50 countries throughout the world conduct a continuing program of scientifically meaningful environmental measurements. The measurement protocols were designed by teams of scientists and educators to be appropriate for primary and secondary students and to generate accurate and reliable measurements for use by the international science community. GLOBE students transmit their data to a central data processing facility via the Internet, receive vivid images composed of their data and data from other GLOBE schools worldwide, acquire information from a variety of sources, and collaborate with scientists and other GLOBE students and communities worldwide in using these data for education and research.

Post-Conference Workshops

Two Post Conference Instructional Design and Technology Workshops were conducted on the Island of Hawai'i.

Using the Computer as a Learning Tool in Studying the Solid Earth System.

Nir Orion, Weizmann Institute, Israel, and several of his graduate students conducted the workshop.

This all-day workshop was designed for school educators and college teachers of geology. Participants met in the University's computer lab to learn about several aspects of using the computer as a learning tool. Those aspects included: a) the computer as a tool for organizing and presenting knowledge, and b) acquaintance with software especially designed to enhance spatial visualization and to instruct in solid earth processes. Participants also evaluated the Internet as a resource for Geoscience instruction.

Designing Earth Systems Education Curricula.

Leaders were William Hoyt and Raymond Tschillard, University of Northern Colorado and Dan Jax, Bexley Middle School (Ohio).

This all-day workshop was designed for middle school and high school teachers. Participants engaged in an integrated field and classroom experience. It began in the rain forest along the Wailuku River near Hilo where they engaged in sample field activities. Following lunch they conducted sample secondary school earth systems classroom activities. Time was devoted to a discussion of strategies for redesigning and implementing curriculum change to meet national and regional standards.

Engagement Sessions

Certain presentations were highlighted as lending themselves more specifically to demonstration and participant interaction than the poster format would allow. Those presentations are featured here with their abstracts. Laure Wallace and Hiroshi Shimono presided over the sessions.

Rethinking Natural Science-An Interactive Earth System Secondary Level Curriculum.

Rebecca Slayden-McMahan and Lanette Gunderson,
College of Education, Austin Peay State University,
College Street, Clarksville, TN 37044 USA.

Participants experienced a collection of twenty original board games designed to teach science to middle and high school students from an interdisciplinary perspective. The subsystems of the natural world were surveyed and presented as interactive systems. Each of the interactive games was developed using information from both printed and electronic sources. Science content included in each game was presented to workshop participants in the format of conceptual webs which demonstrated the interrelatedness of concepts and subconcepts. The games demonstrated a thematic curricular format of instruction integrating traditional content of science and social studies. They are designed to implement a 3-dimensional instructional approach in science education which is student-centered. The games package provides simulation experiences during game play and cooperative learning lead in activities which allow for greater student application of thinking skills and problem solving. Each game includes resource materials and minipulatives. These games are copyrighted and include a teacher's manual. The following games were demonstrated:

Animalia
Arachnids
Archaeology
Bat-Mania
Ecosystems
Entomology
Functional Physics
Geo-Logic
Human Body
Growth and Development
Man's Effect on the Environment
Meteorology
Oceanography
Paleontology
Pond Ecosystem
Rainforest
Scientists at Work
Space Odyssey
Trees
Whale Song

The Heimaey Eruption, Iceland: The First 24 Years.

Alan Morgan, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, CANADA N2l 3G1

This was a video-tape presentation documenting the eruption on the island of Heimaey a small island off the coast of Iceland occupied by a fishing village. The program illustrated the interactions between volcanic activity and its impact upon humans, their society and economy.

The decade between 1963 and 1973 was one of extreme volcanic activity in the Westman Island Archipelago. Surtsey appeared in November of 1963, followed by Surtla, an undersea volcano at year end 1963, Syrtlingur in October 1965, Jolnir in late December 1965, and Surtsey again (1966 - mid-1967). Six years later Eldfell commenced activity on Heimaey, some 20 km north of Surtsey. This relatively small basaltic volcano caused the evacuation of the town of Vestmannaeyjar and displaced over 5,000 people, some 2 percent of the population of the country.

The eruption on Heimaey was quite unexpected and remarkably quiet. A two km fissure opened across the island, missing several homes by less than a few hundred metres. Fortunately the inhabitants were able to evacuate the settlement within five hours due to the Westman trawler fleet being in port, and with the aid of aircraft from the U.S. naval base at Keflavik. During the first few weeks homes were destroyed by pyroclastic debris—bombs breaking into houses through roofs and windows, and the weight of water-saturated ash that broke rooftops and walls.

The second phase of the eruption (mid-February to late April) involved the advance of lava into the town. Lava had flowed from the fissure within hours of the onset of the eruption, but after the partial collapse of the tephra cone things became serious. The rescue workers used boats to spray the front moving into the sea and set up several dozen diesel pumps to take seawater from the harbour via pipes to the landward flow. The idea was cool the face of the lava front. It is difficult to judge whether the apparent success was due to the spraying efforts or to the diminishing output of lava from the volcano. This stage of the eruption was also marked by gas emanations from the volcano, and low-lying areas of the town had to be treated with caution at times when the air was still.

The final stage of the eruption came after the volcano had ceased activity in late June. This involved clearing the town, an evaluation of the lava field, and what was to be done with the community. Within one year most of the initial cleaning and rehabilitation were complete. The residents used the tephra to extend the runways at the local airport and to provide building foundations for new homes to replace those lost in the eruption. The town continued to pump fresh water from the mainland, and the lava field was used to provide a geothermal energy resource that kept the community almost self-sufficient in heating energy until June of 1991. The water from the mainland was used in space heating and eventually distributed in homes and businesses as hot tap water. The "bonus" of having a recently quiescent volcano also contributed to the tourist potential of Heimaey.

Changes in the Culture of Science Education in the UK and Some Implications for Education about the Natural Environment.

John A. Fisher, School of Education, University of Bath, Claverton Down, Bath, UNITED KINGDOM BA2 7AY

For over 200 years there was a tradition among the clergy of the UK for research and writing about the natural world, particularly about their own local environment. This 'amateur' tradition spanned the time of the Rev. Gilbert White, who wrote 'The Natural History of Selborne' in 1788, to the Rev. William Keble Martin who spent 40 years preparing the illustrations for 'The Concise British Flora' which was published in 1965.

Since the 1930s this tradition has been continued and developed, to a considerable extent, by secondary school teachers. Significantly, much of the work was actually carried out in their schools and often involved the participation of school students. Some of this work was more academic than others and the results varied in the degree to which they were made available to a wider circle, but for a period of about 30 years, many students gained enormous benefit from being part of those activities.

Not only were they learning by observing and sharing aspects of the work but the teachers became identified as those who 'practised what they preached' and in doing so became inspirational role models for nearly two generations of students. There were values which were shared between 'master and apprentice' as they participated in a common interest. In doing so an active science culture developed in many schools which gave to students a greater sense of being part of a learning community. Well known examples of such teachers were Earnest Neal of Taunton College who wrote the definitive work on the Badger, Wilfred Dowdeswell who did much to establish the science of ecological genetics through his outstanding work on British butterflies and John Myers whose geological studies of Staffordshire underpinned his inspirational teaching and established an important regional centre for geological study.

This scientific culture in schools can be more widely exposed by searching the professional literature. Covering the period from 1945 to 1995, The *School Science Review* (the quarterly journal of the ASE), has been sampled periodically and the content, author and origin of the samples analysed. This enables us to mark, during this period, when school teachers were actively publishing scientific articles in a journal intended for fellow teachers.

Preliminary work suggests that it is possible to correlate the changing pattern in publications with changes to the organisation of the school system, to methods of science teaching and to changes in the science curriculum. The critical aspect being, that if a scientific culture in school brought particular qualities and values to the educational process, then how might we be able to encourage and promote the development of such cultures in the face of policies which seem to work against such cultural values and systems?

A major constraining factor seems to be the National Curriculum and the effect it has had on the autonomy of teachers and how they perceive their professional roles. It is widely acknowledged that the National Curriculum, (which attempts to provide a standardised system of science education and an equality of entitlement), has led to a 'rounding down' in student attainment and expectation. Furthermore, many believe that a 'quality assurance' system which is based upon a system of content control and Attainment Targets has produced a 'box ticking' mentality among very many science teachers.

This, of course, runs contrary to the model where teachers were once assumed to have a wide, thorough and more philosophical understanding of science and were given the space and the professional responsibility to develop an appropriate learning environment and teaching programme. The best teachers did this exceptionally well and there are still a few teachers remaining who can remember times when such practices were regarded as normal and also the influences which they had on pupils. Many of these teacher/scientists taught much of their courses in the field and thus introduced natural systems as a key part of their work. They also used their personal interests or research to support their teaching and to provide the cultural underpinning to the learning process.

Within about 10 years the professional experience of most teachers will be limited to that of a mechanistic and functional system designed to 'deliver' a 'training in science' and knowledge of times when science teachers were actively interested and involved in science, as part of their professional role, will be lost. When that point is reached the way back will then be very difficult.

Individualizing Instruction in Geological Sciences for Children with Disabilities.

Larry Lowrance and Donald Luck, Austin Peay State University, Box 4545, Clarksville, TN 37044 USA. Debra Lowrence, Kenwood Middle School, Clarksville, TN USA.

The presenters discussed a project, Science and Mathematics and the Handicapped (SMATH), which developed a procedure to individualize instruction in the sciences for any child with disabilities. Over 200 teachers were trained statewide during 1995–96 in Tennessee, and many of these developed and taught instructional units in the geological sciences. Specifically presented were the individualization model, the distance learning format for teaching the model to teachers in the schools of Tennessee, and samples of geological science units that were taught during that year to children with disabilities, as well as the adaptations made so these children can learn the concepts being taught.

The individualization model, called branching of instruction, can be applied to any process oriented instructional lesson plan for content areas in math and science. It is based on individualization of instruction according to the age/developmental level, learning style, motor abilities, language needs, attention or behavioral needs, and sensory needs of each child. These characteristics are considered in planning a lesson whether the child is educated in a regular classroom in an inclusive educational setting or in a self contained special education classroom. The presenters feel that students with disabilities, when receiving instruction in traditional content areas such as geological science, often are inattentive, sometimes disruptive, interfering with the learning of others, and frequently do not learn up to their teachers expectations. Data were presented to show that, when these students' individual learning needs are included in the planning and implementation of instructional units, such concerns significantly lessen.

The presentation included a Powerpoint display on the content, the branching model, completed branching lesson plan forms for various groups of children with disabilities, and a demonstration of a teaching lesson on tape.

All-Conference Field Trip

All conference participants attended a field trip to Hawai'i Volcanoes National Park on July 28, 1997. The field trip was organized by Laure Wallace and sponsored by the United States Geological Survey (USGS). Special assistance was provided by Don Swanson of the Hawai'ian Volcano Observatory (HVO), the Hawai'i Volcanoes National Park, Center for Science Education at the University of South Carolina (USC), and the Center for the Study of Active Volcanoes at the University of Hawai'i, Hilo (UHH).

The complex interactions of volcanic systems, atmospheric conditions, the adaptation of flora and fauna, and the overlay of Hawai'ian culture framed the field trip discussions. Each stop examined some aspect of the Earth system and reflected on how that component is defined by other interacting systems. Two stops also involved attendees in participatory learning about the interactions.

Stop 1: Uwekahuna Overlook; HVO and the Jaggar museum

Topic: Pele and the USGS

Leaders: Arnold T. Okamura, HVO, and T. Leianuenue Reviera, National Park Service

Uwekahuna is the summit of Kilauea Volcano, where native priests offered their chants to Pele, the Hawai'ian Goddess of Volcanoes. Park ranger Reviera related the cultural significance of the site to the native Hawai'ians, and explained why the location is sacred. Geologist Okamura gave a brief history of HVO and defined the role of the USGS in mitigating geologic hazards. Participants then toured the Thomas A. Jaggar Museum and the Hawai'ian Volcano Observatory.

Stop 2: Southwest Rift Zone

Topic: Guided inquiry in field experiences–interpreting Earth system interactions

Leaders: Don Swanson, USGS—HVO, and John Carpenter, USC

A field trip experience can enhance participants' problem-solving skills and engage students in a learning experience in which they solve an Earth systems interaction problem. At this site, participants worked in small groups to investigate two questions, one related to the climatic conditions of the site and their influence on the island as a whole, and the second interpreting the patterns of rocks to determine the sequence of geologic events that had occurred. The guided inquiry approach was effective in developing experience-based questions that recurred in discussions throughout the conference.

Stop 3: Halema'uma'u Crater Overlook

Topic: Living with volcanic air pollution; monitoring seismic activity

Leaders: Rob Klee and Paul G. Okubo, USGS—HVO

Kilauea releases about 2000 tons of irritating sulfur dioxide gas (SO2) each day during eruptive periods. Some of this combines with cloud moisture to form acid precipitation, and the gas itself may contribute to respiratory problems for humans. *Vog* is a hazy form of air pollution produced when SO2 and other volcanic gases react chemically with oxygen, moisture, sunlight and particles. The pH of Vog can be as low as 1.5-2. Vog is also suspected in numerous health problems all over the island. This stop included a walk among fuming vents to the edge of the crater, and a demonstration of a portable seismograph to look at changes in earthquake patterns and possibly predict changes in the volcano's behavior. There are 65 seismic stations on the island, with 40 on Kilauea itself. Seismic monitoring has taken place on the island since 1912.

Stop 4: Devastation Trail

Topic: Guided inquiry—investigating geologic and botanical history

Leaders: Darcy Bevens, UHH, and Deiter Mueller-Dombois, UH Manoa, Emeritus

In this location participants examined the patterns of vegetation growing on the barren lava, and also noted the varying characteristics of the lava itself, from olivine-rich cinders to solid flow areas. Questions were generated and explored regarding what characteristics of plants adapted them to life on the devastated area, where the plants could not grow and why, and how some plants escaped devastation while others were killed. The remarkable variety of plants in the harsh combination of land, weather and lack of water was discussed.

Stop 5: Na-Huku Lava Tubes

Topic: Earth systems interactions in a lava tunnel

Leaders: Bobby Camara, NPS, and Jim Kauahikaua, USGS—HVO

Development of lava tubes within a lava flow allows lava to be transported great distances while losing very little heat. The lava tube at this site formed 350–500 years ago, and it has become a center of biological (including human) activity. Roots from the rain forest penetrate lava tubes and host ecosystems of blind invertebrates uniquely adapted to life in perpetual darkness. Cracks in the walls allow water in. Hawai'ians made extensive use of lava tubes as sites for water collection, for habitation, burials, and some religious practices. The Cave Management Program of the National Park is responsible for protecting these unique Earth systems.

General Sessions

Five presenters representing science, education and culture provided lectures that carried out the theme of the conference.

Native Perspectives on Natural and Cultural Resources

Kepa Maly, Cultural Resources Specialist, Kumu Pono Associates, Hilo, Hawai'i, USA

The speaker was introduced by Rosanne Fortner, The Ohio State University.

Abstract. Our cultural diversity leads us to look at the natural and cultural resources (or landscapes) in different ways and to apply different values to them. In a traditional cultural context, the native people of Hawai'i see cultural resources as not only things of a physical, geographic, practitioner's or archival nature, but they are also natural resources—i.e., the earth and elements around it.

Hawai'ian traditions of creation: Man is a part of, rather than apart from, the natural environment.

In a Hawai'ian context, the spiritual beliefs, cultural practices and cultural landscape of the Hawai'ian people were intricately bound to the natural landscape of the islands. The culture was as dynamic as the environment that gave it life. Indeed, Hawai'ian tradition tells us that the sky, earth, ocean, natural phenomena, nature and animate and inanimate forms were the embodiments of Hawai'ian gods and deities. In a Hawai'ian genealogical account, Wakea (the expanse of the sky) and Papa-hanau-moku (Papaù Earth-mother who gave birth to the islands) also called Haumea-nui-hanau-wa-wa (Great Haume aù Woman-earth born time-and-time again) and various gods and creative forces of nature, gave birth to the islands. The same forces were also the parents of the first man (Haloa) and from this ancestor all Hawai'ian people are descended (cf. David Malo, 1951).

In this genealogy, Hawai'ians were the youngest siblings of the Earth-family; nature was the source of the culture. In the 'ohana (family) it was always the responsibility of the younger generations to care for those who came before them (the earth family). Thus, in the Hawai'ian mind cultural and natural resources are inseparable. Many kupuna (elders) note that their elders instilled in them the understanding and belief that "Being close to nature was to be close to God." Another Hawai'ian thought that is expressed by many kupuna is "Malama ka 'aina, a malama ho'i ka 'aina ia 'oe iho" (Care for the land. and the land will care for you in return).

Aloha! I'd like to thank you very much for allowing me to join you this evening. From my sense of who you are by your organization, I think that we share a kindred spirit. It's important for us to know who we're speaking to and where we come from. In a Hawai'ian context, we share who we are, our roots, our origins because it establishes a rapport for a relationship. I was raised on the islands of O'ahu and Lana'i. I am not of Hawai'ian ancestry, but was taken as a "*keiki hanai*," like an adopted child, by a pure Hawai'ian family, that helped to raise me. Their name was Kaopuiki. Today, you were at the land that goes by the name Ka'u, at the volcano, the craters of Kilauea-nui, Halema'uma'u, and Kilauea-iki. The names show the relationship that people felt with the land with the environment around them. The couple that brought me up were in their late seventies when I went to live with them and I was one of thirty-two children; sixteen of their own, and 16 others that they cared for. We spoke Hawai'ian at home. As I grew up, I was blessed, I know, to have had the opportunity to touch the spirit of this land. And from those *kupuna*, the Hawai'ian word for elders, I've been given the opportunity to bridge, to step across, and work with many people throughout the islands.

Today, as I see a part of the theme of your conference, "Earth Systems" or "Earth as a System," it tells me something that's very important and I think also something that's changing the way we look at the earth and the environment around us. Before, we tended to isolate ourselves, to separate ourselves, looking at each little part individually. No one realized that,we needed *integrated resources management*, or caring for, and seeing how all of these facets are bound together, particularly for those of you who are educators. How important it is to find little things that people, that your students, can associate with, because if we just hit them with the science, if they don't see that people share a relationship with the earth and the environment around them, it is almost meaningless. So, this evening, I'd like to share with you a little bit about where you are here in Hawai'i. But, also, importantly, I would like us to participate in the Hawai'ian slang, the term that's used today, "talk story." If you have some questions, such things that you brought with you, the ideas or thoughts about Hawai'i, or ideas that were sprouted or planted today or are now germinating, perhaps I can help to answer some of those questions or provide you with some guidance as to how you might find the answers to those questions.

A little later, I'd like to take the opportunity to interact with you . Before that, I'd like to share with you two sayings that my elders taught to me. As teachers, I think many of you will appreciate this. There is an ancient Hawai'ian saying, *"A'ohe pau ka 'ike i ka halau ho'okahi"* (not all knowledge is found in one school). So I might share something with you that is a little different than what you have heard or what you came prepared to hear and know. I have come from another school. This is important as we go though life and realize that there are many sources, many paths, for us to take to ultimately reach the same goals or objectives.

The other saying that is important to me, one that has given me, in many ways, my life, is *"O ka mea maika'i malama, o ka mea maika'i 'ole kapae 'ia,"* as my Tutu papa or grandfather shared with me, it means, "That which is good of what I say, keep; that which wasn't appropriate, or perhaps, which may even have caused pain, set it aside rather than holding on to it." Because you know when we hold on to the negative, when we hold on to things that are, at times, even unpleasant, they tend to fester; something like the pits in the volcanoes themselves, and that isn't very healthy. So, here we are, I ask you to think of those things and I would like to share a little bit about our island home.

As you're probably aware, the islands of Hawai'i, in a geological perspective, are all volcanic in origin. As we learn of hot spots and plate tectonics, we are taught that the island of Hawai'i today is made of five major volcanoes. Kilauea, where you visited today, is the youngest of the five. If I recall, the oldest section of land to date known around or above surface of Kilauea is around 200,000 years old. Kohala, the northernmost of the five volcanic mountains on this island, Hawai'i, is about 800,000 years old since it rose above sea level. Within that time, an island mass of over 4090 square miles was formed as five volcanoes rose from the ocean's floor through 18,000 feet of ocean; when you take the weight of these islands causing depression even on the surface of the earth at the ocean's floor, it took 18,000 feet of growth to reach sea level. Then, you look at Mauna Kea, the single tallest mountain on earth from its true base; from its place of origin, is almost 32,000 feet high. So, in 800,000 years this island has been formed.

Maui, Moloka'i, Lana'i, and Kaho'olawe, four islands today, are roughly 2 million years old. At one time, those four islands were all joined together, with low isthmus' stretching between the larger volcanic mountains. Interestingly, in plate tectonics we learn that the earth's crust has shifted, and we've been taught scientifically that where we stand today, Maui sat here also. The islands originated here. Oahu, about 2 1/2 million years old, Kaua'i, is about 3 million, Ni'ihau and the Leeward islands extending all the way up to the archipelago, reach to nearly 30 million years old. All of them began here at this spot on Earth.

This story is interesting because we can find that in the area of subduction in the Aleutian chain, that the plate subsides, being crushed and melted back where it came from. The islands of the Emperor chain once started, it is believed, not far from where we are today, also.

The reason I share this story with you is because the Hawai'ian people look at the earth and through the isles they traveled through generations of migrations into Polynesia. They had a similar story. But their story tells us in the earliest of times, Wakea, the eyeball of the sky, the sun and the expanse of the sky itself, with his woman companion, Haumea-nui-hanau-moku, the woman who gives birth to the earth, who has been born time and time again herself, had a child. Their first child in the legendary, genealogical context was the island of Hawai'i. While that's not geologically accurate, when you take a look at the sense of family, what we see is that the eldest was the largest, the strongest. And then each of the islands were born down the chain to these various creative forces of nature. In the Hawai'ian context, the genealogy tells that these creative forces of nature and the lesser spirits took their body forms as parts of the environment itself. The winds, life at the peaks of the mountain, the valleys, the rivers, every small fish, shrimp, every plant, every fern, and out into the oceans. Everything was a part or the body form of a spirit of a god or creative forces of nature. If you've ever seen a patch of a rainbow, the Hawai'ians call it *punohu*, and in the oceans, *punohu* is the slate urchin. It was also believed that everything had a partner. And if you were in need as a human, you could call on these various forms of nature because they were believed to be animated, alive, imbued with the power.

You see, in this genealogy, not only were the islands born and then all the forms of nature, but the last child to be born was Haloa, man itself. And from this ancestor, Haloa, the long stalk, or the long breath, all of the Hawai'ian people came. When they looked at the environment around them, they didn't see themselves as being apart from it; instead they were a part of it. They were part of a family. These islands were their elders. Indeed, when you take a look at Hawai'ian families, we see that the word for elder is *kupuna*. It can be broken down into two words; *ku* means "to stand," *puna* is "at the spring" or" source of water." Interestingly, that's the word for elder, "one who stands at the spring or source of water." But you see, the Hawai'ian word for water is *"wai,"* and *"waiwai"* is the Hawai'ian word for wealth! So we see that even in the family, in context and relationship with the earth, Hawai'ian families knew that their "*kupuna*," their elders, stood at a source, at a spring. They were a source of wealth. The word for family itself, "'*ohana*," is descriptive of the growth of taro plants, the *'oha* and the off shoots of the taro, *keiki*, the offspring, the decedents come from that. They were looking at the earth in their relationships to all of the plants, all life forms were believed to be related.

Thus, when the Hawai'ian people looked at the geology, the ocean, at the winds, storms, when they look at the stars, *hoku*, they were seeing their ancestors, their relatives. They believed that if you care for the earth, the earth cares for you. In fact, many of our own people somewhere back in our history believe that destructive natural phenomena were indeed the wrath of the earth, the deity, the creative forces of nature for our failure to adhere to or to respect the earth, the environment around us. So, in this context in Hawai'i, we find that the Hawai'ian people loved also to honor the earth, to sing songs, to chant in praise of its beauty, to ask for a freeing of the path that we might travel even, that we might take this journey, that we might be inspired. If I go to gather a plant, if I go to fish or to take a handful of seaweed from the shoreline, I should ask permission first, because we're a part of the earth, not apart from it. It's not ours to just take and abuse, but we must respect it, because everything is alive, everything is a part of a system.

I'd like to share with you this evening, particularly since most of you went to Kilauea, one of the chants that my *kupuna*, my adoptive elders, taught me. It may give you a little bit of the sense: I hope that you may even be touched by the spirit to see how the earth reaches out and greets you, says *aloha*. The Hawai'ians believed everything around us was a live being, that when they chanted, as in this one example, they called out; "Respond, woman who dwells on the mountain peaks, mountain ridges, the mountain that is the source of the mist. Listen, we can hear this woman, the earth itself for whom leis, or garlands of *lehua* blossoms *lama* blossoms have been strung. This woman tells us to look at the earth, to see the waterfall as it leaps down the cliff of Kawaikapu. We smell the fragrance of the ocean, of the *lipoa* seaweed and we call upon all the creative forces of nature to descend and inspire us, free us, let our path be open that we might travel, and that we might accomplish our tasks."

That's a rough translation of this *mele* (chant) that I'd like to share at least a part of with you so that you can hear it in a traditional context . Remember, the Hawai'ians' entire history was handed down from mouth to ear, generation to generation from the gut, not from the heart—all we feel in our heart is a little murmur. But when you really feel it, it gets in your gut. So, they've shared this from here [gesturing to his gut], this relationship that they had with the earth around them.

[Chant followed.]

Traditionally, the people called to the earth, the creative forces of nature around them. They acknowledged their relationship to all things. I believe that while I'm talking more specifically about Hawai'i today, you come from perhaps as many as 30 countries. There are things that we can take home, that we can share, to animate, to help bring to life. I went to school on Lana'i, one of thirty-two students in the graduating class, the only *haole* (Caucasian) and I'm sure that I was one of the *kolohe*, or rascals of my teachers. I had such difficulty with many aspects of education because I couldn't see how it related to me. As a problem student, I would encourage you, and I'm sure that you're here because you are good teachers, to think of ways to inspire, to animate the lessons for your students.

Just a few weeks ago, I was privileged to take a group of teachers and students up to Kilauea. The leader of the group was a seventh grader when I led a group of students along the Ko'olau mountain range of O'ahu. What a blessing to have someone come back and say, "I was so inspired by what you shared with us and how you introduced the mountain to us and its life, that it made me want to become a teacher and share the science and share this history with students." These were the kinds of things that we hope to be able to do, even if we can plant one seed and watch it germinate and grow and become something that then reaches out to provide shelter and nourishment, or history to a future generation.

There are many things that we could talk about. What I would like to do is to ask you to share your questions or thoughts with me. I will try to share them back so everyone will know what we're talking about. I think it always works much nicer when we can interact and talk story with one another. Are there some questions or thoughts about some of the things you've seen or heard about these islands

QUESTIONS

"What were the destructive or violent powers of Pele while she was such a high deity; how did the people strike a balance for dealing with the destruction?"

It is an interesting question. How many of you think a volcano is just violent and destructive? In Hawai'i, the story is very different. When I was telling you that story about how the islands were born to the creative forces of sky and earth, Pele was one of the daughters. Her uncle, Lono-makua, is the god of rains. Her sister, Namakaokaha'i, is the ocean, her brother, Kamohoali'i, the elder brother, was the shark-formed god, that led the canoes from Tahiti, from distant lands, to the Hawai'ian islands. Another sister, Poli'ahu, a woman who wears a garment upon her breast and her body is snow. And on down the line through all of these creative forces of nature. The Hawai'ians didn't look at Pele as destructive; they had fear and awe, but it was not destruction. In fact, the word *eruption* to me is almost kind of vulgar. The Hawai'ian description of eruption might be *hu mai ka pele*, (the lava rises, overflows). That's simple. Here is a beautiful description for when you see an eruption, "*Ke ha'a mai la ka wahine*," meaning that Pele the woman dances on the plains, going to the ocean. You might ask, "Why does she go to the ocean?" Well, as is the case at Kilauea, at one point where you were visiting today, one of the tales of the eruptions in antiquity says that a man made a promise to her and failed to keep that promise. As a result, Pele went down, chased him and consumed him; thus, the flow occurred. So you see, there was a relationship that the people felt with this deity! Pele was so revered, so awe inspiring and loved by her people that the families that were descended from the clan or class of people were *Kaula Pele*, the seers, the prophets, the chanters. The descendants of the Pele line even had their "*iwi*" or bones bundled and taken to Kilauea and placed there. The next time an eruption occurred the families were benefited. They could call their *kupuna* "Here am I, my ancestor, my grandparent, your descendent, *mo'opuna*." They believed that they could call and even ask for special consideration. There are accounts even in historic times of lava flows (and I'm sure there are great geological explanations for it) in which someone would put a little flag marking the boundaries of the property. As the flow is coming down, it opens up, goes right around, and the land of that family is preserved and protected. The explanation was "Oh the kupuna, the grandparents were there watching and they took care of you." So, Hawai'ians didn't look at volcanoes necessarily as destructive and violent forces of nature, rather as a part of the environment to which they were related. I think that's important. Thank you for your question.

Next was a question about the origin of offering gin or liquor to Pele.

Prior to the arrival of Captain Cook in 1778 when he stumbled upon this islands by mistake (in other words I'm saying he didn't discover them), people used *'awa* or something more commonly called *kava*, as the supreme offering of a drink. Then things like rum, brandy, and gin came in. One of the more recent, prominent native practitioners of chant and dance honoring Pele, says one for Tutu and one for me. She happened to like gin a whole lot, so when people leave liquor, it is a way of leaving something personal. In fact, the *'ohelo* and *'ohelo kau la'au*, are native members of the family, sort of like native members of the cranberry, blueberry family here in the islands. It was so sacred because this native plant was a body form of one of the older sisters of Pele who couldn't assume volcanic form. When native visitors would go up to Kilauea, they wouldn't dare travel through the land without first picking some of the *'ohelo* and offering some to Pele. After offering it, they would ask her, "May I please also eat some? Now we are one. We are together." It was the way that they made a relationship of oneness with the environment and earth around them.

Question. "The people of New Zealand and other people of Polynesia have many interesting and culturally rich stories about their lands. Are there stories then about how they got here, their own migrations or their relationships?"

In part, if I paraphrase that question, it might be, yes, there are stories. Indeed, one of them tells us for the people of New Zealand and Hawai'i that an ancient chief, Natoroirangi, which in Hawai'ian is Nakoloilani, one of Pele's brothers, left Hawai'i in search of a new home. He left Kalae, the southern point of this island or in that vicinity. When he reached a cold barren land, it was so cold and covered with snow that he called on his elder sister Pele to send some of their sisters to bring fire to those islands. And that is a Maori tradition as well. Thus Pele was the one who helped bring active volcanism to those islands.

Throughout Polynesia, there are stories–common denominators, links, ancestral ties, and relationships. There are many accounts of traveling these vast oceans in their small double-hulled canoes. Native seafarers making these journeys of discovery. There are many accounts, and the New Zealand one is a quick example.

Question paraphrased. The gentleman teaches on Navajo lands and was interested in the similarity of stories about the dualities of sky, earth, and these relationships and how many similarities there seem to be between the cultures. Is this sense of place, this cultural attachment, to stone, to plant, to these resources, is it just historical or does it continue today?

Obviously, it continues today, but culture, like the environment, is dynamic, and you must remember that after 1778, the Hawai'ian people were thrown into a revolution which ended in 1893. The actual overthrow of hereditary rulers of these islands was by a group of American marines under the order of the American ambassador to these islands. Much has been lost and there are many fragments that are being filled in today. Even one of the most prominent writers in Hawai'i in the middle 1800s, John Papa I'i, a member of the royal court under the Kamehamehas, was born around 1804–1805. He lived under the ancient *kapu*, their system of restriction (taboos), and he became a devout Christian. In the 1850s he was a prolific writer, even the title of works in Hawai'ian was "*Na Hunahuna Mo'olelo Hawai'i*" (Fragments of Hawai'ian History); because in the 60–70 years or so since western contact, the Hawai'ian population was so decimated primarily through disease, but also as a result of the warring factions between chiefs, when Kamehameha was bringing his kingdom of Hawai'i together.

So many things were going on that we, today, are left with only the fragments, bits and pieces. But we still honor that cultural attachment, that depth of relationship. It's so easy for us to say...You build a golf course and take the natural landscape and level it. If it had a river or a pool in it, you usually fill and then they make new ones. Developers don't see that in the Hawai'ian context, place names indicate that there is cultural significance to a place. Everything is known and has a name. These things have cultural significance, and this is alive and well in Hawai'i. So this cultural attachment continues, but it is also evolving and changing. We are moving away from our roots; even the language as it's spoken today is different than the way language was when it became a written language. Different in how it was written and spoken at that time. Culture is dynamic as well, and our goal is to try and be able to retain some of the glimpses, some of the threads that tell us what was, so we can know where we're going.

Question about when I was introduced, there was some mention of development and voices of the elders reluctant to speak before development processes to share some of the cultural attachment.

You see, the natural and cultural landscapes in many people's culture are one and the same with their values; you can't separate them. The reluctance in speaking is that they do not wish confrontation. As a Hawai'ian, you don't air your dirty laundry; you don't argue and fight in public.

Many of the people that I work with as a part of environmental impact, environmental assessment, special management area, applications, various things as we're looking at land, trying to preserve some of that sense of place, are in their 70s and 90s. They are the last people that had contact with their *kupuna*, some of their elders were born in the1850s, who were then brought by their grandparents who were born close to the time of contact. Just the last link we have with people who actually heard firsthand, or secondhand, what it was, how life was lived, why places and resources were important.

What I do throughout the state is work on oral history and ethnographic programs, collecting histories, letting native people and others that have a strong sense of identity and understanding of the history of these lands share some of their thoughts, their history, why the land is important to them, letting them share their ideas in a safe environment. Why you don't dig in burial grounds and desecrate the land; why you don't change the water flow. Wouldn't you think it would be so obvious, particularly for you who are involved with the earth, earth as a system (your theme here), to realize that what you do in the rain shed, in the forest, on the mountain, has a direct effect on what happens in your fisheries? But, it seems some people never get the picture. They don't realize how these relationships, the rain stops there, the whole thing with your foraging fish, your mullet and milk fish and things like that producing food for the carnivorous fish. All these little things are so intricately bound together. My goal, in talking about this with you, it's like preaching to the saved already. But the idea is, if we can just share the depth of this relationship and how everything is tied—one to the other—we can share with people why it's in our best interest to take care of the earth. If you take care of it, it's going to take care of you.

Bottom line...these islands are the most isolated group of islands on earth, separated by over 2000 thousand miles. Once every ten or twenty to forty thousand years, some lifeform managed to cross that vast moat, the ocean, and get to these islands. And it didn't need deep roots, poisons, thorns, aggressive growth patterns, big fruits or flowers and all these things because there were no mammals by the way, no humans. Suddenly those defenses weren't necessary, if I can make it a little personal, and humanize the issue a bit. So life got here and in two hundred years we've had over 100 extinctions in these islands. Extinction is a natural process. It occurred here naturally perhaps once every ten thousand years. Look at what we've done in amplifying that rate. Today, Hawai'i has the highest number of extinct species in the United States, the highest number of endangered or nearly extinct species. It's really awesome when we look at this story.

But you know, here's the thing I would send home with you, don't forget your own doorstep. Don't forget where you come from, culturally and where you live, because in Hawai'i, you know what was the first thing to verge on extinction after western contact? When these islands were assaulted by a mass of diseases and new resources? People! In one hundred years, nine-tenths of the population was decimated. They had no immunity to the diseases, to the things that were brought in. So, specialization, adaptive radiation—maybe we should look where we're going as a people, also.

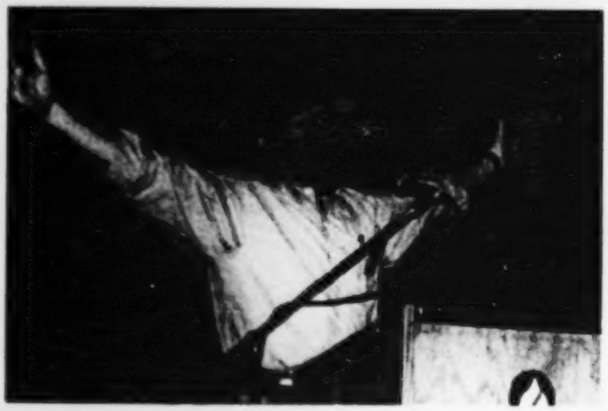
I'll close on that. And I want to say, "*Mahalo*" thank you very much for allowing me to share some of your evening and this time with you. Keep the good, set the bad aside.

Aloha

Earth Systems Science and World Standards for Science Education

Rodger W. Bybee, Executive Director of the Center for Science, Mathematics, and Engineering Education at the National Research Council, Washington, DC.

Dr. Bybee was introduced by Vic Mayer, The Ohio State University (Emeritus).



Abstract. The goals of science education traditionally have emphasized the knowledge of science. The Earth sciences were often included within physical science or geography, less often in life science. They were presented without explanation of their contributions to the understanding of the Earth system. Now that the National Science Education Standards have been developed in the USA, Earth sciences are identified as a distinct discipline, parallel to the physical sciences and the life sciences. The three are of equal importance to science education. While the Standards specify outcomes that could be identified as the traditional content of Earth science, they spell out the importance of systems thinking and the relationship of Earth studies to the lives of students and society in general. Greater attention is being focused on how and why studies of Earth processes and interactions can contribute to personal and social perspectives about science. The latter are standards that complement the Earth systems view, and should be recognized as such by Earth science educators. The combined standards enhance students' understanding of issues in using and managing Earth resources and developing a sustainable future.

The challenges of achieving science literacy for all students are grounded in the question of what individuals should know, value and do as citizens of Earth. Earth systems science addresses this question not only in the content of instruction but the methods of teaching/learning, how learning is assessed, and what policies, programs and practice serve the goal best. Earth system science programs developing independently around the world can inform efforts toward global science literacy.

In his presentation Dr. Bybee acknowledged two people in the audience who worked on the Standards: John Snow was on the content working group and was influential in seeing that Earth systems is an important theme in the National Science Education Standards in the U. S. Rhonda Brooks worked on the teaching group, another equally important group of contributors.

I thank the organizers for inviting me and providing an opportunity to spend a few minutes with you talking primarily about the National Science Education Standards developed in the United States. For me this is a fairly rare and very important opportunity because science literacy is a global issue. We do have to attend more and more to the international community and learn how to talk to one another, share ideas, and address common challenges.

Many U.S. educators in the audience [show of hands] had input into the standards at some point in their development. Although I am the one talking about the standards today, the standards in fact were developed by the community. The process was taken seriously, and it was a long, detailed and very public process. In the end, all of the difficulties contributed to a quality document. You can see that part of the community literally sitting in this room had input and responsibility for the product.

What I will do is use the experiences with the National Science Education Standards in the U.S. to point out some things that might be relevant to world standards as well.This will lead to some recommendations that one would consider in such development. I think that this group literally, as I look through the participants list, has the right combination to begin development of such standards. By that, I mean there are leading scientists here, there are leading science educators, and there are leading science teachers, all of whom have deep interest in Earth systems sciences as an approach to education. The combination of scientists, science educators, and science teachers was a very strong force in our work on the standards. Imagine if the standards were only completed by scientists: they would look very much like what one needs to go into postdoctoral work in the particular scientist's area. If they are only completed by science educators, there would be a heavy loading of "this is a constructive model here" and "some research needs to be done there." If the Standards were only completed by teachers, we would likely have a number of "how to" activities and, basically, lessons and units for teaching.

I overstate my case, but the point is that each group brings a certain set of perceptions and strengths to the whole enterprise of developing standards and the business of teaching Earth system science. I would characterize my work, along with several people working at the National Academy of Science, as trying to achieve an appropriate balance among those three groups, and to get as close as possible to something that was appropriate scientifically, was usable within the educational arena, and especially, was important and appropriate for students. Thus, you have the right mix of people here. I would encourage you to think about how to work together, especially in the international front, as you may proceed with developing world standards for Earth system science.

Now, my plan for the time I have. I'm going to give a very brief personal note of my entry into Earth sciences. I'm going to talk about the National Science Education Standards as the major thrust of the talk, and then some implications for world standards, in particular, world standards for Earth system science.

I'd like to give you some relevant personal history. When I started my undergraduate work, I spent about the first five years studying biology, and in particular, ecology. I had to take one course in the Earth sciences, as in those days was the distribution requirement. To this day, I can remember all of the details of that course. But, most importantly, what it did for me was it brought many major ideas in science together. A key point is that I had been studying ecology. The ideas in ecology made me ready to think about Earth systems when I got to the geology course. I remember being very, very excited about "the big picture:" "wow! it rains and there's weathering and erosion and all kinds of things that affect life!" That is the kind of excitement I heard from many of you on the conference field trip. It's the expression of the excitement and the interest expressed in questions such as: "how did this happen?" and "what I can I learn about it?"

As I finished college, I did my student teaching in the Earth sciences, one of my first experiences with the Earth Science Curriculum Project (ESCP). I continued teaching in the Earth sciences for about five years before I went back to graduate school.

The reason I interject the personal note is to point out that I have a very deep commitment and personal interest in the Earth sciences and what I would now characterize as Earth system sciences. I can remember teaching undergraduate courses at the University of Northern Colorado. I used the spheres approach, actually the systems approach–"We are going to study the lithosphere, the hydrosphere, and the atmosphere." I got really excited about where those spheres interact, because that's where the action is! I can recall the undergraduates' indifference to the words. So there's another whole dimension if you're trying to get people engaged in learning. You need to do something besides say the words Earth system science. That has carried me forward into more and more thinking about the educational issues as opposed to strictly the content.

When we started the standards, there was no overwhelming support for Earth sciences as a separate category of content. A number of people, particularly in the physical sciences, suggested that the key topics of weather, land, oceans and space belonged in categories in the physical sciences. The concept of biological evolution and the origin of life on earth could be subsumed in the life sciences. In the face of such challenges, we had to make the argument that it is legitimate to have Earth and space sciences as a category of standards. The argument didn't go on very long, but if nobody had raised the issue, it could well be that the Earth sciences would be subheadings and additions to other subject matter standards.

I am going to give a brief overview of the standards, and you'll see that one of the things we did from the very beginning was to identify more than content. Standards are (or ought to be) more than defining the content of instruction. This recommendation should not be a surprise to this group. Just as you are interested in the Earth system and understanding various components of the system, education itself is a system. Education includes more than defining the content. So, as we worked on the standards, we broadened the domains to be considered. The list below outlines the big picture of the standards. In addition to the content, we also have standards for teaching, assessment, school programs, educational systems, and very importantly, for professional development.

National Science Education Standards Include:

- Teaching Standards
- Professional Development Standards
- Assessment Standards
- Science Content Standards
- Science Education Program Standards
- Science Education System Standards

As we consider how implementation of standards might progress in the educational system, think about what happens from kindergarten through grade 12. For example, the list of presentation titles at this meeting indicates there is a tendency to think horizontally across a discipline, whatever your grade level happens to be. We tend to think of what has to happen at 8th grade from the beginning to the end of the year. If you're designing a program,or instructional materials, there's a tendency to think horizontally over a year's curriculum.

One of the things the Program standards encourage all of us to do is think vertically as well. If you take the content of Earth systems science and think from kindergarten through grade 12, you have opportunities over thirteen years in the U.S., and generally the same in most other countries. How does one think about earth systems science across the spectrum of school years and experiences? What do you do to enhance the opportunities students have to learn vertically in the educational system? For example, you can take inquiry, or any of the various unifying themes within the school's science program, and develop it at any level. That's basically what the Program standards are about.

At this point someone usually says, "Don't you know that if you are going to do anything at all about changing the curriculum, my administrator (or the school board or the public) is going to have to support teachers?" There's a set of people and groups and components of the educational system that have a lot to say about earth science teaching, but they don't come to classrooms! They have budgets, they set graduation requirements, and they set license requirements for certification of earth science teachers. They are components of the system that are very important and we thought it was prudent to put some standards in that at least acknowledge the need to coordinate the other components in support of the changes implied by the Standards.

Science Education Program Standards focus on six areas

- The consistency of the science program with the other standards and across grade levels
- The inclusion of all content standards in a variety of curricula that are developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects
- The coordination of the science program with mathematics education
- The provision of appropriate and sufficient resources to all students
- The provision of equitable opportunities for all students to learn the standards
- The development of communities that encourage support and sustain teachers

Next we consider the Professional Development standards. The greatest single resource we have in our educational system right now is the classroom teacher. We need to attend to that resource and not overuse it; make sure that we can replenish and keep that resource functioning effectively and efficiently. That's to say, attend to the professional development of school personnel. It's easy to focus on curriculum materials and assessment and so on, but all of us know that curriculum is a means and teachers provide the final structure for what happens in the classroom. Therefore, what teachers know about Earth system science and how they are able to teach become essential. Professional Development standards address these issues.

Professional Development Standards focus on four areas:

- The learning of science content through inquiry
- The integration of knowledge about science with knowledge about learning, pedagogy, and students
- The development of the understanding and ability for lifelong learning
- The coherence and integration of professional development programs

As I make the transition to the content standards, I note a theme of mine–the Sisyphean question. In mythology, Sisyphus rolled the rock up the hill, but the rock kept tumbling back down. We have to keep rolling the rock up the hill, the educational hill in this case, by asking, "what should the scientifically literate person know, understand, and be able to do after thirteen years of school science?" The answer is they ought to know something about earth systems science. How does that happen? What does the content of school programs look like? For us, we developed a series of unifying concepts and processes, some very big ideas—equilibrium, evolution, models, explanation, and so on. We're dealing with science as inquiry: physical life, Earth and space science, science and technology, personal and social perspectives, and the history and nature of science.

Looking back in educational history (at least in the United States and perhaps many other countries), to actually have Earth and space science as a standard, as a standard in and of itself is an important statement in the history of science education. Usually Earth system science has been embedded somewhere else, if at all.

What you state as a Standard becomes very important. For example, we even had Earth scientists suggest that we embed "science in personal and social perspectives," or the "history and nature of science," in Earth systems or life science! It makes a difference whether you have these as a *separate* standard, or you say a particular, such as earth systems or history, is *part of* a standard. If life sciences and physical sciences are listed, why not just put another point in those to say "history" or "science in personal and social perspectives? It makes a difference because there is a limit, or at least a point of diminishing returns, to how much you can put into a standard. Up to a certain amount, people will attend to and get very serious about the standard when they implement it in actual teaching or the design of instruction materials. More than that will be ignored or just assumed to be learned. We make time for something that is a discreet standard.

As we formulated the standards, we were very sensitive to students' developmental levels. For example, fewer, more concrete concepts at the lower level. For Earth/space science, younger students basically encounter properties of Earth materials and objects in the sky. It is as simple as interacting with a small child: what do you see and what can you talk about if you look down at the ground? If you look up at the sky? What can you see and what can you talk about? How do you describe what's going on? Begin Earth systems education where young people are, with the basics and the human perspective.

As children mature, we can proceed to the structure of the Earth system, Earth's history, and the Earth in the solar system. So we progress to major conceptual organizers in grades 9 through 12–energy in Earth systems, geochemical cycles, evolution of the Earth system, the origin and evolution of the universe.

I should make a point relevant to world standards. In the *National Science Education Standards*, science content is described in grade level sets, K–4, 5–8, 9–12. We were careful not to define what should be in an 8th grade Earth science course. We avoided indicating an amount of time that should be devoted to the particular subjects. Certainly, we all had ideas about these issues. There ought to be Earth system science courses, the standards say, but in the United States, states have the power to decide when and how those courses should be presented. The sure demise of national standards would have been to say "there ought to be an 8th grade Earth science course and this is how you ought to teach it." The states would have rejected what appeared to be a national curriculum. Instead, the standards describe the content, but as the content is transformed into instructional materials, state frameworks, and assessment strategies there are many different and acceptable forms of implementation. The Standards also do not say how to structure the content within the curriculum. Variety is possible because of their openness. There is a parallel if you're thinking about world standards. That is, it would be best to define content for general ages/grades and leave specific curricular decisions to those who use the standards.

I would encourage you to think about how to emphasize Earth systems science in the early years. Most of the precollege presentations at this conference have to do with middle school and high school. The elementary school is a very important area, and one ought to think about seeking opportunities to enter into the elementary system. Likewise, at the high school: what are the opportunities there? At least, in the United States, where most Earth science courses are at 8th grade or 9th grade, we should ask, "How could I design the Earth systems program so it is a complement to other science courses?" Or if a state or district is thinking about an integrated program, "wouldn't the Earth system approach be ideal for that?"

Now I want to point out something from the Earth systems perspective that is the ideal opportunity for this community. Few of the physical scientists and not all biologists are looking at the "science in personal and social perspectives" standard and seeing implementation opportunities. Yet populations, resources, environments, natural hazards, risks and benefits, and science and technology in society are excellent topics to incorporate Earth systems concepts. What we tried to do is consciously identify the major scientific and social categories that bridge sciences and society. These are areas of concern that will be with us for generations. By stating the standards in broad terms, we open the option for instructional materials developers to align with standards. For instance, every adolescent is engaged if the subject is some kind of catastrophe. To do a unit on natural hazards would be exciting and fun for teachers and certainly engaging for students. A program in the United States called "events-based science" has tried to capitalize on this opportunity for teaching and learning science.

Each of the major categories in the Earth science standards expands to offer more depth. However, most readers of the document call everything in the document a standard, regardless of its general or specific nature. Note that the stem of the standard is very carefully crafted. For example:

"As a result of their activities in grades 5 through 8, all students should develop an understanding of…"

Science Content Standards for Earth and Space Science

Grades K–4	Grades 5–8	Grades 9–12
• Properties of earth materials	• Structure of the earth's system	• Energy in the earth system
• Objects in the sky	• Earth's history	• Geochemical cycles
• Changes in earth and sky	• Earth in the solar system	• Origin and evolution of the earth system
		• Origin and evolution of the universe

The standard could have said "scientists indicate that we should know about structure of the Earth system." What we did was intentionally word that standard as a result of their activities. Who is the referent? The students, the children, of course. So we're saying their activities. Again, underscoring the set of grades, not a particular grade level. All students should develop an understanding of...— all students. That is an explicit statement of equity built into each standard. We state the standard as a goal and then pay particular attention to those under-represented groups, those who have special needs in the educational system, to help them achieve the goal.

The conceptual organizers are the ones that most people read first. There is a statement following the conceptual organizers called "developing student understanding." This section suggests what it may take to develop students' understanding. We included some of the kinds of misconceptions that students might have, and hinted at some instructional strategies.

Early criticisms of the standards indicated that the conceptual organizers were too broad—"structure of the earth's system" did not, for example, give teachers clear indicators of what to teach. In subsequent iterations we developed what we termed fundamental concepts and principles that underlie the standards, as a way of saying what we meant by structure of the earth system. We appealed to the scientists to provide the five or six major ideas that are fundamental to that conceptual organizer. The number was limited on purpose, requiring the scientific community to have serious discussions and debates about what is it that should be listed under there. These are the things one ought to be teaching.

I want to point out inquiry, a longstanding theme that I would encourage your consideration of as you might move forward for world standards.

Inquiry processes include: identify questions, design and conduct investigations, use appropriate tools and techniques, develop descriptions, think critically and logically to make the relationship between evidence and explanation. We must challenge students to support their explanations with evidence. What would count as evidence to support their particular idea? Recognizing evidence, analyzing it, examining alternative explanations and predictions. In the standards we tried to shift the emphasis from what we've talked about as "the processes of science," which primarily consisted of experimental methods, to the processes of critical thinking, reasoning, and logical argument. Of course, such cognitive abilities use processes of science (e.g. observation, inference, and formulation of hypotheses). Earth system scientists inquire using historical and observational data as well as experimental data. This conference used inquiry as an excellent component of the field trip to the Hawai'i Volcanoes National Park.

Let me conclude with some comments about the educational system. As you move forward in thinking about world standards, recognize that Earth systems science could indeed be a central organizing idea for an

Science content standards for "Science as Inquiry"

As a result of activities in the grades listed, all students should develop abilities necessary to:

Grades K–4

- ask a question about objects, organisms, and events in the environment
- plan and conduct a simple investigation
- employ simple equipment and tools to gather data and extend the senses
- use data to construct a reasonable explanation
- communicate investigations and explanations

Grades 5–8

- identify questions that can be answered through scientific investigations
- design and conduct a scientific investigation
- use appropriate tools and techniques to gather, analyze, and interpret data
- develop descriptions, explanations, predictions, and models using evidence
- think critically and logically to make the relationships between evidence and explanations

Grades 9–12

- identify questions and concepts that guide scientific investigations
- design and conduct scientific investigations
- use technology and mathematics to improve investigations and communications
- formulate and revise scientific explanations and models using logic and evidence
- recognize and analyze alternative explanations and models
- communicate and defend a scientific argument

integrated approach to school science. There is no question about that. One would have to think very clearly about different standards such as content, the curriculum and the school science program. Recognize from the beginning there are some critical parts to the educational system and some of those components are not going away. There will be administrators, there will be state departments of education, there will be course syllabi, there will be national tests, et cetera, et cetera. If you were interested in carrying Earth systems science forward, keep these points in mind:

1) Find and use critical leverage points. College admissions might be good place to look; state assessments, curriculum developers, requirements for graduation from high school.

2) There are boundaries. There are people who do not allow the flow of information and resources across the boundaries within the educational system. In terms of the world standards, what is it that won't impede and may facilitate border crossings? What is it that will allow flow of information and ideas across the different boundaries internationally? What is it that will stop at a border?

3) Flow of resources and information. What do we need to do and think differently about the flow of resources. What do different people need? The National Governor's Association and its National Goals Panel (U.S.) meet tomorrow. They want to know what policies they should set in their states. What should they be doing now? Envision and prepare for those discussions, remembering the need for different kinds of resources for different groups.

4) Feedback is critical. A major idea in systems thinking is the role of feedback in the system, especially human systems. What is it that provides the balancing or the negative feedback in the system? What is it that's reinforcing or positive feedback? Once standards are in place, they serve the function of providing feedback if people are attending to and are committed to them. Standards serve to reset the thermostat, so to speak.

5) Identify the energy sources. Just as surely as energy is important in the earth systems standards, keep your eye on the energy if you want to know what's going on. In the educational system, power is the parallel, and in many cases, it's political power. Anticipate where that power is and how to work with it. Understand it, and not only accommodate it, but sometimes use it if you want to achieve the very important mission that I think you're all about.

Should you move into world standards, the National Research Council is interested. We will contribute to the distributed leadership that can help carry your efforts forward to the next century. An earth systems approach is critical to citizens understanding their planet. I encourage your efforts and wish you the best.

Thank you very much.

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The Significance of Earth Systems Science (Education) in the Curricula of Japan and other Asian Countries

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Dr. Kumano was introduced by William Hoyt, University of Northern Colorado.

Abstract. Human activities are seriously impacting the functioning of the Earth system. Our use of water, minerals, land and other natural resources has increased more than ten times during the past two decades, and future increases in population and economic growth could create critical conditions for the existence of humans.

It is surprising that we are entering the age of reformation or innovation of science education in the world. Many advanced countries have been in the process of major reform of science education nationally or locally. Likewise Asian countries: Korea, China, Indonesia, Thailand, Philippine, Japan, and many others are rapidly reforming education. In the case of Japan, now is the period for developing a framework for major reform of education in the context of life long education. The reformation of science education will follow this new framework.

Earth Systems Education (ESE) is one of the major science education reform movements. It has been developed by the researchers, teachers and organizations with connections to the Earth system. Development has occurred through projects funded by the National Science Foundation, and other sources. ESE has been introduced to Japan by two groups: Dr. Hiroshi Shimono and others (1994, 1996), and Mr. Nakano and Dr. Osumi (1993, 1996). Also, importantly Dr. Victor J. Mayer worked in Japan for about a year and has visited Korea frequently. He energetically disseminated Earth Systems Education to both countries.

In my presentation, I will start with a focus on the recent situation, including the present problems in secondary earth science education in the U.S. and Japan. Through this analysis, I will contrast the similarities and differences in these countries. I will then reexamine Earth Systems Education for the Japanese context. Thirdly I will focus on the significance or possible significance of Earth Systems Education through some pilot research I have conducted.

The speaker, Yoshisuke Kumano, with Rajasekhariah Shankar of India and Chan-jong Kim of Korea.Shankar and Kim contributed perspectives from their countries.

1. PRESENT SITUATION, PROBLEMS OF SECONDARY EARTH SCIENCE IN THE U.S.

1-1. Introduction

In Japan, high school physics and earth science are endangered subjects. Fewer and fewer students tend to choose physics or earth science for their entrance examination every year reducing the demand for this high school course. The main reasons that earth science is not being selected are (1) we don't have a compulsory earth science course any more; (2) almost no private universities or colleges offer earth science as one of the subjects for the entrance examination; (3) competitiveness of governmental universities has decreased; (4) students choose those science courses that will help them on the specific entrance examination for their desired university; (5) private examination companies have gained too much influence in shaping students evaluation for entrance examination. Are there any solutions for these problems in earth science education in Japan?

In the U.S., serious problems in secondary earth science education are shared with the problems of earth science education in general, including college and university education and informal education. At the same time, there are many programs and projects that support improvements in earth science education. It is worthwhile to examine the present status and problems of secondary earth science education in the U.S. Also, it is important to review the history of secondary earth science education in the U.S briefly. Furthermore, examination of new projects and programs in secondary earth science education could be the help needed to find a resolution of the problems of Japanese secondary earth science education. Finally it is necessary to have a discussion about secondary earth science education with American researchers and teachers of earth science education. In the first part of this paper we focus on the present status and problems of secondary earth education and its related areas.

1-2. Recent Status and Problems of Secondary Earth Science Education in the U.S.

Before we start our analysis, it is important to review relevant general educational statistics of U.S. schools. According to Estimates of School Statistics (1988-89), the highest fall enrollment in public elementary schools from 1978 to 1989 was 25,506,170 (1988-1989) and the lowest enrollment in the same population was 23,726,904 (1983–84). From the fall enrollment of 1983–84, the number of students began to increase. On the other hand, the fall enrollment in public secondary school constantly decreased from 1978 to 1989, however we can expect increases to begin in 1990 as reflected in the elementary school trends.

The enrollment of elementary and secondary level students from 1899 to 1979 is summarized in the Digest of Education Statistics, 1981 (Grant and Eiden, 1989).

Table 1. The Enrollment of Elementary and Secondary Level from 1899 to 1979

1899–1900	16961249
1909–10	19643933
1919–20	23463898
1929–30	28551640
1939–40	28257000
1949–50	28660250
1959–60	42012076
FALL 1969	51429691
FALL 1979	46920665

From *Digest of Education Statistics*, 1981, p. 8

From Table 1, we find that enrollment of elementary and secondary students generally increased until the period between 1959 and 1960 when a rapid increase occurred through fall 1969, then a slow decrease began and continued until 1984. Average grade enrollment of all elementary school and high school can be roughly approximated as follows:

Table 2. Grade Enrollment of Elementary and Secondary Level from 1899 to 1982

Year	Elem	High
1899–1900	2004556	174850
1909–10	2272793	278849
1919–20	2556596	625044
1929–30	2869172	1202950
1939–40	2558264	1782494
1949–50	2628991	1613252
1959–60	3764846	2399952
FALL 1969	4273772	3604575
FALL 1979	3590651	3825308
1981–1982	3533333	212000

Source: Welch et al. (1984)

1-3. Recent Enrollment in Earth Science

The following are the relevant data concerning science education enrollment taken from Report of the 1985–86 National Survey of Science (Table 3).

Table 3. High Schools Offerings of Selected Science Courses

Biology, First Year	99%
Biology, Second Year	53%
Chemistry, First Year	91%
Chemistry, Second Year	28%
Physics, First Year	81%
Physics, Second Year	11%
Astronomy	8%
Ecology, Environment Science	15%

From: Weiss, I.R., 1987.

Weiss reported that although 52 percent of schools offer a course in earth science, earth science constitutes only 3 percent of all classes offered for all grades 10 to 12 (Weiss, 1987). This means that although the bare majority of schools offer an Earth Science course, very few sections of the course are taken within each school as compared to other science courses.

Between 7th grade and 9th grade, 70 percent (23/33.3) of all junior high school students in the U.S. elected a course of earth science and 9 percent (3/33.3) of all high school students in the U.S. elected earth science (Table 4 and 5).

Table 4. Content of Secondary Science Classes by Grade Range

Courses	Percent Classes 7th–9th Grades	Percent Classes 10th–12th Grades
General Science	21%	1%
Biology, Life Science, Env. Science	31%	53%
Chemistry, Physics, Physical Science	20%	42%
Earth/Space Sciences	24%	3%
Other	4%	1%
Sample Size	n=658	n=1050

From: Weiss, I.R., 1987, *Report of the 1985-86 National Survey of Science*, p. 26

Interesting statistics are given in Welch et al., (1984). Although there was a decrease in enrollment in science courses for grade 7–9 from 1977–1982, the percentage of those students enrolled in earth science courses increased from 13.9 to 14.4 (Table 6). In general, a decrease in general science and an increase in the life sciences enrollment were documented for that time period and age group.

In the same manner as shown in Table 6, changes in science enrollment, grade 10-12 (1977–1982) are analyzed by Welch et al. (1984). Proportionate to changes in total science enrollment, earth science enrollments increased (Table 7). While the enrollment of all earth sciences decreased from 256 thousand students to 242 thousand students, ratio to the total enrollment in all sciences increased about 0.8. This is because the total school enrollment decreased by 2.24 million from 1976-1977 to 1981–1982. It is possible to say from Table 7 that there are proportionally more students who want to study in the earth sciences. These data reflect only a

Table 5. Most Commonly Offered Science Courses

Courses Grades 7-9	Percent Classes	Courses Grades 10-12	Percent Classes
General Science	20	Biology, 1st year	35
Physical Science	18	Biology, 2nd year	7
Biology	8	Other courses	24
Other Courses	6		

From: Weiss, I.R., 1987, *Report of the 1985-86 National Survey of Science*, p 25

Table 6. Changes in Science Enrollment, Grades 7–9 (1977–1982)

	1976–1977		1981–1982		CHANGE	
COURSE	N	RATIO	N	RATIO	N	RATIO
General Science	3655	29.5	2707	26.7	-948	-2.8
Life Science	1902	15.4	1939	19.1	37	3.7
Earth Science	1721	13.9	1459	14.4	-262	0.5
Physical Science	1955	15.8	1493	14.7	-462	-1.1
Biology	724	5.8	533	5.3	-191	-0.5
Integrated Science	265	2.1	246	-19	-19	0.3
Environmental Science	114	0.9	115	1.1	1	0.2
Other	367	3	208	2	-159	-1

From: Welch, et. al., 1984.

single year of enrollment. We have to be careful of thinking that "Only 56 percent of students in grades 10 to 12 are enrolled in science" means that 44 percent of all the U.S. students have no science background at high school. We need a three-year analysis for the purpose of understanding nationwide enrollments. Otherwise we may misunderstand total student enrollment in science in both junior high school and high school to be nearly half of what it actually is. But most school districts require one or two years of science credits for graduation from high school and two or three years of science in junior high school. A concern is that too much emphasis is placed on biological science and chemical science, which in turn leads to problems in college enrollment in science. This can be the cause why we have so many biology majors in college or university and why we have so many biology teachers for junior high school and high schooi. We need certain balance among the science course enrollments in the high school.

1-4. Teachers Present Situation Concerning Earth Science in the U.S.

College and university earth science related courses are the weakest area as a discipline background for the junior high school science teachers. Biology is the most common field of specialty in science for junior high school science teachers (Table 8).

Table 7. Changes in Science Enrollment, Grades 10–12 (1977–1982)

	1976–1977		1981–1982		CHANGE	
COURSE	N	RATIO	N	RATIO	N	RATIO
Earth Science	167	4.4	118	3.7	-49	-0.7
Astronomy	23	0.6	26	0.8	3	0.2
Oceanography	24	0.6	40	1.2	15	0.6
Physical Science	42	1.1	58	1.8	16	0.7
Total	256	6.7	242	7.5	-49	-0.7

Source: Welch et.al. (1984)

Table 8. Junior High Science Teacher Preparation

Courses in Teaching Discipline	Life Science Teachers	Earth Science Teachers	Physical Science Teachers
0	0%	22%	2%
1	1%	16%	3%
2	9%	14%	5%
3	3%	16%	5%
4	11%	14%	8%
5	9%	11%	14%
6	5%	6%	9%
7	5%	2%	5%
8+	56%	19%	47%
Unknown	1%	3%	2%

Source: Weiss, I.R. (1987)

More detailed research about the academic preparation of science teachers was done about Idaho state teachers (Heikkinen, 1988). The average total credits of earth science courses at the college or university taken by Idaho earth science teachers at the time was 11.3. Only 17 percent of all Idaho earth science teachers had an endorsement for earth science teaching while 76 percent had general science endorsement, and 54 percentage did not have a methods course in science education. These numbers from Idaho state shows that Idaho state had the similar characteristics as federal statistics which were developed by Weiss (1987).

Estimated supplies of secondary biology, chemistry, physics, general science, and mathematics teachers by state from 1980 to 1982 were summarized (Gerlovich and Howe, 1983). Each state and each discipline was rated as: 1=surplus, 2=slight surplus, 3=adequate, 4=shortage, 5=critical shortage. The highest mean shortage across all states for three years was among physics teachers (4.45), second highest shortage was found in Chemistry teachers (4.16) and earth science teachers (3.82). The supply of biology teachers was adequate to slight surplus. From 1980 to 1982, more science teachers were needed. It is possible then to infer that most new earth science teachers do not have enough earth science background. In other words earth science majors do not choose teaching jobs.

Furthermore, the problem of shortage of science teachers is not simple since we don't have enough students who will remain as science teachers. About fifty percent of new science teachers can easily find better paying jobs within five or six years of graduation from college. Hounshell and Griffin (1989), from questionnaire and interview research, summarize many reasons why we have such a critical shortage in science education. Some major reasons are: (1) The salary is too low and within 15 years the amount of salary doesn't increase at all; (2) Social status is quite low; (3) Identity as a professional work is lacking among the teachers and communication among teachers and administrators is uneasy; (4) work setting is poor; (5) high quality teachers and low motivated teachers work together.

1-5. Changes of Enrollment of Earth Science Majors and their Job Orientation

It is worthwhile to identify the changes in enrollment of earth science majors and their job orientation in attempting to solve problems in secondary earth science education. The American Geological Institute conducted a "Geoscience Student Survey" in 1989. Data for undergraduate students shows that up to 1983 there was increasing enrollment in earth sciences followed by a dramatic decrease starting in 1986 (Table 9). On the other hand, graduate enrollment remained steady.

According to the *Geotimes* (February 1989), sudden enrollment drop of undergraduate earth science majors starting in 1986 was caused by the depression of demand for petroleum engineers where roughly 30 percent of graduates had been employed. Moreover, because of the great decrease of undergraduate enrollment, AGI predicted that few of the geoscience faculty expected to retire in the next five years would be replaced (Claudy, N., and Kauffman, M.E., 1988). This situation causes rather serious problems for secondary earth science education in the U.S.

2. PRESENT PROBLEM OF EARTH SCIENCE EDUCATION IN JAPAN

2-1. Introduction

In 1872 the Japanese school system was established by the Ministry of Education. People who studied abroad immediately following the Meiji Restoration did this. Science methodologies and practices were imported from Germany, England, France, and the U.S. and many foreign scholars were invited to work in Japan. These experiences led many to believe that everything brought in from foreign countries was valuable. Nobody recognized that Japan was becoming a world leader in science. The Japanese people continued to study and work to gain prominence, often sacrificing their leisure time.

The Fundamental Law of Education and School Law of 1947 were promulgated under the influence of the U.S. and the 6-3-3-4 organizational system for school was started. Again, Japanese society had to start from

Table 9. U.S. Enrollment in Earth Sciences 1978–1988

ENROLLMENTS	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
UNDERGRAD	25399	28674	30495	31987	34343	36893	29722	31149	20584	15179	14898
GRADUATE	8843	9112	9881	10180	10108	10408	9695	11381	10917	9650	9111

the beginning following the end of the Pacific War. As during the Meiji era, by a conglomeration of factors necessary to overcome the devastation of war, people did their best for the good of a greater society. These unusual efforts as a nation made the miracle of the current Japanese economic development possible. This is because citizens believe that they needed, and therefore developed, a sophisticated centralized education system. However, times change. Japanese society is being projected into an era where people feel they have little experience to guide them.

Japan has many environmental problems which citizens believe are the result of the development of science and technology. In Japan, the National Course of Study (National Curriculum Standards) is reformed every 8-10 years. The last reform was in 1981 for elementary school and in 1982 for upper secondary schools. Educators and citizens not associated with science believed that too much emphasis had been placed on science education. As a result the Ministry of Education felt pressured to amend the National Course of Study and in April 1989 a new National Course of study was agreed upon which de-emphasized science and placed more emphasis on social issues focusing on individualization, internationalization, and information literacy. Mr. Nakayama (1988) says that this reform is a type of science-technology-society theme in a Japanese context.

Although this reformation has started, Japanese education does not change easily because of intensive competition on the National Entrance Examination for colleges and universities. These examinations are forcing teachers to cover the entire contents of the textbook to help students understand the basic concepts of science. The science teachers continue to follow the 1960's curriculum of the U.S. because the pre-service education at our colleges and universities has not changed significantly over the past 25 years. Furthermore, all our curricula (not only science but other subjects as well) focus on a specific 'Scope and Sequence' where curricula are developed in a spiral structure. This means that the same concepts are presented in several different grades. It appears that Japanese science education is ignoring a new philosophy of science and learning psychology and a new sociology of science. Reflecting all of the problems in science education in the Japanese society, it is predicted that "A Crisis of Science Education in Japan" will happen within the next ten years. To prepare for the days ahead, a new research program including with the current form of the U.S.'s ESE and STS approaches must be established. As Dr. Grayson (1984b) stated: "For the first time, Japan is in the position of having to advance the state of knowledge, do advanced research, and create its own technologies. Japan must develop a creative, more knowledge-intensive industrial structure."

2.2. General Information about Earth Science Education in Japan

It is of concern that earth science and physics are the endangered subjects among science courses in high schools in Japan. This is a rather shocking idea for the people who are teaching earth sciences in the schools. Table 10 shows that the amount of science for the elementary school decreased after 1977. Also Table 11 shows that a similar situation is happening in the junior high school. Table 12 shows the enrollment percentage of science courses from 1970 to 1994. Only 7.4 percent of the students of all high schools in Japan are now taking "earth science."

Table 10: Changes of Percentage of Science Classes in Elementary School

	1947	**1958**	**1968**	**1977**	**1989**
Science Classes	94.7	100*	100	88.8	66.8
All Classes	97.9	100	100	93.8	93.8
Science/All	10.8	11.2	11.2	10.6	8

*100% of Science Classes means four classes a week. (Karaki, 1996)

Table 11: Changes of Percentage of Science Classes in Junior High School

	1947	**1958**	**1968**	**1977**	**1989**
Science Classes	100*	100	100	83.3	75
All Classes	96	96	100	86.4	86.4
Science/All	13.3	13.3	12.8	12.3	10.7

*100% of Science Classes means four classes a week. (Karaki, 1996)

According to statistics in Table 12, the enrollment percentage in earth science is getting smaller and smaller. According to the statistics developed by the National Institute for Educational Research of Japan (NIERJ, 1990) , seventy percent of students in all colleges and universities in the Kanto area (Tokyo vicinity) did not take earth science in high school. This means that the Kanto area had more students (30 percent) who took earth science in high school compared to other areas in Japan. Biology was the favorite science subject for the non-science course students followed closely by earth science. For science course students, earth science was the least science subject selected.

2-3. Problems of Earth Science Education at College Level

This situation is probably worse than that in the U.S. in that we don't have enough earth science specialists in the university. For example, we have three members in earth science (out of eighteen science faculty members) in the College of Education, Shizuoka University. Especially the private colleges or universities have few courses in earth science. So most of the time, a professor is invited from governmental universities. All this means that number of graduates whose major is earth science is the smallest among the four areas of science. In the same way, the number of science teachers in junior high school or high school whose major is earth science is the smallest among four.

2-4. Problems of Science Teachers

Most science education teachers in the junior high school do not have enough background in earth science. So they are uneasy teaching earth science and conducting earth science field trips in spite of high recommendations for field activities contained in the National Curriculum Standards developed by the Ministry of Education. Earth science field activities are rather difficult to conduct at junior high school because the numbers of science classes are getting smaller. Also there have been safety concerns among teachers and administrators. Sometimes a principal will not allow teachers to conduct earth science field activities.

2-5. Problems of Entrance Examination

If you have a student who would like to study in the field of earth science, the high school science teacher might advise that she or he take Biology, Chemistry or Physics first. Should the student become a science course student, these courses would provide better background for success on more college or university entrance examinations. This means that this student might change his major from earth science to other science major simply because an earth science examination is offered within a smaller number of colleges or universities.

3. REFORMATION & INNOVATION OF EDUCATION IN JAPAN

In July 1996, the Ministry of Education announced the First Report on Guidelines for the 21st Century Education in Japan. In this report, the status and problems of youth are identified. The number of children within a family has been decreasing year by year. More and more families prefer not to live together with grandparents. The percentage of old people is increasing every year. A mother puts more energy into helping her children in terms of homework or extra study. Children are so busy that they don't have enough time to spend sharing housework with the family. Moreover, our economy has been uneasy and productivity or creativity of our nation is decreasing slowly. By the year 2003,

Table 12: Changes of Percentage of Enrollment in Science Classes in High School

	Physics	**Chemistry**	**Biology**	**Earth Science**
1970	93.8	100	82.6	61.1
1975	82	100	81.2	40.2
1980	77.2	95	80.7	35.1
1985	33.6	55.6	46.3	11.1
1990	34.3	59.5	54	11.2
1994	13.3	55.8	43.5	7.4

(Karaki, 1996)

the school week will be reduced to 5 days. What we need in our society is major innovation or reformation of education. The First Report describes the important philosophical shift in this innovation is to the development of community of learners. If you become a life-long learner, every thing around you will change in terms of academic competitiveness. Indeed the key issue in this innovation will be how many people can move toward being a life-long learner. Stable and systematic approaches are needed in every function of our society. The reference of the detailed program for educational reform can be found on the Internet at: *(http://www.monbu.go.jp/seriesen/00000003/)*.

4. Reformation of Science Education; Emerging Innovative Program; Earth Systems Education, STS and National Science Education Standards

4-1. Introduction

Most American scholars cannot readily see the serious problems of Japanese education and they identify the Japanese educational system as one the U.S. should model. But is that really true? Antonoplos (1986) mentions that some of the research on education in Japan has been of dubious quality and that considerable risk in making or adopting generalizable statements from the literature should be recognized. Grayson (1984b) concludes that the Japanese approach may not continue as a fully successful strategy for the future, and the Japanese will be required to develop their own technologies. Continued economic growth may demand significant changes in Japan's present strategies for technological development and, in turn, in its educational system. Grayson's ideas are so reasonable about our science and technology education that the Japanese government needs to consider his points more fully.

With reform of the Japanese National Curriculum Standards and its National Course of Study (1989), Jacobson & Takemura, et al. (1987), Nakayama (1988), and Takemura (1990) explained that the reform of National Course of Study of 1989 was done with the essence of Science, Technology and Society (STS); an approach to science curriculum popularized in Great Britain and the United States. The direction of the reform may be correct, however essential analysis of new philosophy of science and science education, a new sociology of science, and recently popularized learning theories or psychological approaches and appropriate instructional strategies are needed for the reformation. We need more science, technology, environmental considerations and cooperation with other subjects and to look seriously at other approaches to science curriculum philosophy and development, such as the Earth Systems Education approach. This new concern resulted from data that revealed that 94 percent of Japanese students are enrolled in high school and that most of them were unable to understand science. Monbusho (Ministry of Education in Japan) then tried to change science curricula to a more activity base science or integrated science learning with other subjects. We really need to develop an innovative science education program for Japanese Society based more on the characteristics of Japanese culture, environment, and society and the needs of the Japanese governmental and economic system.

4.2. Emerging Innovative Programs: Earth Systems Education and STS

As a result of the "Sputnik-shock" in 1957, the U.S. passed a public law called the National Defense Education Act (NDEA). Under this law, psychologists and top scientists (not philosophers of science) got together and developed many curricular materials and textbooks (Yager & Penick, 1987) . The period between 1955-1974 can be called the "golden age of science" (Kyle, 1985). Then came the "Oil Shock" and the emergence of environmental problems. This crisis resulted in a call for a "return to the basics" (Kyle, 1985). There were many attempts at reformation of secondary education, which resulted in a decrease in science offerings and an emphasis on the 3R's (Reading, wRiting and aRithmatic). On October 30, 1970, Public Law 91-516, the "Environmental Education Act" was passed. Under this law and the ESEA (Elementary and Secondary Education Act), many projects and programs were developed concerning Environmental Education.

With NSF funds, Project Synthesis developed four main goals for science education and included an analysis of future needs (Harms & Yager, 1981). These were personal needs, societal issues, career education/awareness, and academic preparation. These goals are quite suited to a complex society. It is also noteworthy to recognize the EESA (Education for Economic Security Act of 1984) because at this moment the U.S., was experiencing an "Economic Shock." Under this law (which in 1989 was later amended to be called the Eisenhower Act after President Dwight D. Eisenhower) and with NSF funds, many programs and projects were developed to resolve science education problems in the U.S. Almost every state has initiated reform of science education in various ways.

The 1980's reform of education, which focused on science, mathematics, and computer science is different from the 1960's and 1970's. Much has been written in support of this latest reform in the U.S. First, philosophers of science are criticizing science education and urging changes in the curriculum and methodology now used in teaching science (Hodson, 1988, Finley, 1983, Wallace, 1989). Second, learning psychologists have conducted research on student misconceptions which indicate student thinking methods and how they are affected in typical science classes (Osborne & Wittrock, 1985). Third, from the sociology of science, there are moves to change science education (Richards, 1988). Fourth, we can find a change of attitude of science teachers toward science education goals (Yager & Penick, 1988). Fifth, we note a large change in student attitudes toward science and teachers. Students want to learn more about societal issues and they are tending not to respect science teachers (Yager & Penick, 1986, Yager, Simmons & Penick, 1989). In order to overcome these problems in science education, two of the greatest efforts can be seen in Science-Technology-Society (S/T/S) as defined by the NSTA position statement (Yager et.al., 1989). A more recent science curricular movement is Earth Systems Education and its more recent offshoot, Global Science Literacy (Mayer and Fortner, 1995, Mayer, 1995, 1996, 1997a, 1997b) .

Earth Systems Education is the major science curriculum restructuring and integration effort coming out of the earth science education community. There has been great effort for developing new curriculum focusing on "Planet Earth" from 1985 by several universities especially the Ohio State University, the Lawrence Hall of Science, American Geological Institute, Geological Society of America and other organizations. The NSF and Eisenhower Law supported many programs. In 1988, a meeting was held, sponsored by AGI and NSTA, to consider a basis for revisions in earth science curricula. Nearly 20 earth scientists from NASA, NOAA, USGS and several universities, as well as an equal number of pre-college teachers and curriculum specialists, met for five days. This conference resulted in a report laying the foundations for K-12 earth science curriculum revisions and eventually the development of the Earth Systems Education program initiated by Prof. Victor Mayer, one of the co-conveners of the conference. Mayer and his colleagues developed and organized "Program for Leadership in Earth Systems Education" (PLESE) supported by NSF from 1990. Out of this program came Earth Systems Education. In this process, there were strong communications with AAAS.

There were four goals developed in the original report of the 1988 conference (Mayer and Armstrong, 1991):

(1) Scientific Thought: Each citizen will be able to understand the nature of scientific inquiry using the historical, descriptive, an experimental processes of the earth sciences.

(2) Knowledge: Each citizen will be able to describe and explain Earth processes and features and anticipate changes in them.

(3) Stewardship: Each citizen will be able to respond in an informed way to environmental and resource issues.

(4) Appreciation: Each citizen will be able to develop an aesthetic appreciation of Earth.

There are ten concepts that are a prerequisite for an evolving 21st century view of planet Earth (Mayer and Armstrong, 1991):

(1) The Earth System is a small part of a solar system within the vast universe.

(2) The Earth System is comprised of the interacting sub-systems of water, land, ice, air, and life.

(3) The Earth's subsystems (water, land, ice, air, and life) are continuously evolving, changing, and interacting through natural processes and cycles.

(4) The Earth's natural processes take place over periods of time from billions of years to fractions of seconds.

(5) Many parts of the Earth's subsystems are limited and vulnerable to overuse, misuse, or change resulting from human activity. Examples of such resources are fossil fuels, minerals, fresh water, soils, flora and fauna.

(6) The better we understand the subsystems, the better we can manage our resources. Humans use Earth resources such as mineral and water.

(7) Human activities, both conscious and inadvertent, impact Earth subsystems.

(8) A better understanding of the subsystems stimulates greater aesthetic appreciation.

(9) The development of technology has increased and will continue to increase our ability to understand Earth.

(10) Earth scientists are people who study the origin, processes, and evolution of Earth's subsystems; they use their specialized understanding to identify resources and estimate the likelihood of future events.

Earth Systems Education as it evolved provided a very broad perception of the nature and basis of science. As a result, ESE can be linked with several subject areas, including all of the science, mathematics, social studies and aesthetic curricular areas such as art. Constructivism is a central focus within the ESE instructional systems. It is central in instructional approaches but, perhaps unique of all curricular areas, in curriculum and program development. In this sense, ESE could be one of the best approaches to parallel the National Science Education Standards published in the US in 1996.

4.3. Implementation of ESE and the Significance for the Japanese Context

There are two groups who introduced ESE to Japan. Nakano & Osumi (1993) had an analysis of ESE. They over viewed ESE and introduced some modules. They examined ESE, comparing it with STS. They found that ESE had much support from the "NSTA Position Statement on STS, 1990". They identified ESE as a restructuring process for existing science subjects and other subjects as well. Nakano and Osumi advised that ESE be introduced more in Japan and should include "Earth Literacy" as a minimum essential for the citizen in Japan. It would also be useful for integrating science and other subjects. Also, Nakano (1996) had a presentation on the features of "Activities for the Changing Earth System." In this presentation Nakano examined eight modules with the connection of seven understandings developed by the PLESE Planning Committee. Nakano identified ESE modules as using constructivist approaches. Again, Nakano insists that ESE could be a wonderful and unique curriculum for Japanese science and technology education.

Another group examining ESE is Shimono and Gotoh (1994). In 1995, Shimono examined Environmental Education and as a major content for EE, Shimono insists the importance of understanding the Earth as a system. Shimono (1996) and his research staff for outdoor study (22 members) examined ESE from the view points of outdoor learning. Shimono attended one of the PLESE teachers program; and its Cincinnati Field Trip. He insists that ESE is a unique and well organized model for Environmental Education. Also, Shimono (1996) developed a position paper for the new Japanese science education curriculum for achieving the understanding of the Earth environment. In this paper, Shimono introduced ESE and its seven understandings developed by PLESE planning committee. His main point is that one of the next frameworks in Japan should be the Earth environment and ESE is the unique synthesized or integrated curriculum which we should invite more.

At most, Mayer (1996) had major symposium on "National Science Standards (USA) and Global Science Literacy" at Hiroshima University. Mayer encouraged many researchers in science education, especially the earth science education area. In this international conference, we have more than ten Japanese people who learned of ESE through him. He visited many schools, institutions, colleges and universities, including Shizuoka University. His efforts in Japan and Korea for the dissemination of ESE had great influences in those countries.

4.4. A Exemplary Module in Japan similar in many respects to ESE

Kumano (1993) reported the results on the module "Mt. Tsukuba" which was a semester long learning process of STS as defined in the NSTA Position Statement. Also, Kumano (1994) reported the results on the module "Global Warming" which was the second, semester long learning process using the STS approach. For the second trial, the purpose of the study was to implement an STS approach in selected science courses in Meikei High School to determine if such an approach could contribute positively to the current reform efforts in science education in Japan. The results are compared with similar ones from the Iowa experiments in the U.S. There is much evidence that the STS approach that is congruent with the Constructivist Learning Model (Yager, 1991, 1992) can result in major achievements for both teachers and students in the U.S. It is also clear that the Iowa model of STS is expanding to other states through National Science Foundation (NSF) supported projects.

However, none of these models has included a move to another culture such as would be the case in Japan. By using the same methodology of module development, an experiment using the STS approach was tried and evaluated in a different cultural setting, Japan, and with the results reported compared with similar ones in the U.S.

A common limitation identified in studies of the effectiveness of STS approach is the lack of information about teacher and student behaviors. The STS approach asks teachers to use constructivist learning strategies, co-operative learning, concept mapping, and the learning cycle, special questioning skills, decision-making skills, and other strategies suggested by student-centered teaching. Little information exists, however, describing what teachers (and students) do while using an STS approach in Japan.

5. CONCLUSION

STS and ESE have similarities because both of them are exemplary approaches to curriculum consistent with the National Science Education Standards (NRC, 1995). There are differences between ESE and STS. One of them is a different philosophy of science and curriculum development. Ways of developing modules are different. STS is more flexible whereas ESE provides a basic conceptual and process framework. One of the goals for ESE includes the aesthetic appreciation of Earth, whereas STS does not address that aspect of aesthetics of science as a major

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framework. But it is rather better for the Asian context to adapt both as the major Science and Technology Education framework for the 21st century. Or it may be possible to develop another approach or framework more appropriate to the Asian community of learners for the 21st century. However, for such a process, we need many educators, researchers, governmental specialists and budgets all together.

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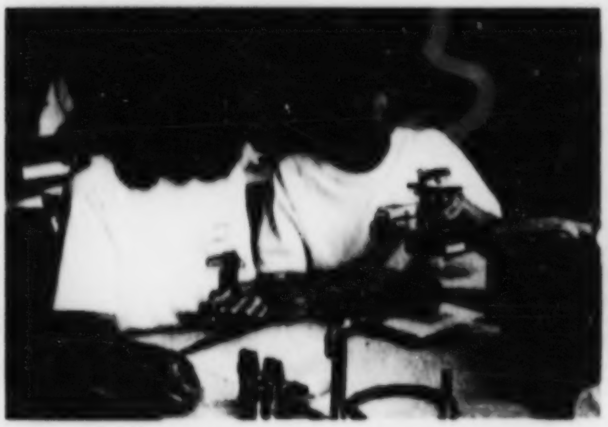


The Island of Hawai'i: Aspects of its Evolution and Earth Systems Interactions

Thomas A. Schroeder, Director, Joint Institute for Marine and Atmospheric Research at the University of Hawai'i at Manoa.

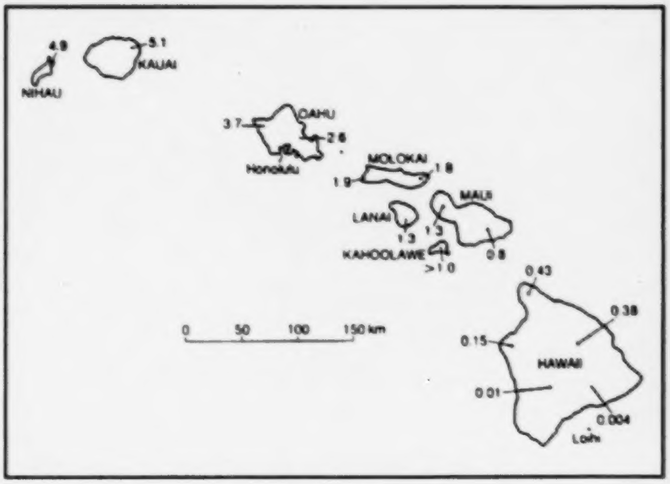
Introduced by Robert Christman, Executive Director, Coalition for Earth Science Education.

Abstract: The island of Hawai'i is the youngest island in the Hawai'ian chain. It comprises five principal volcanoes in varying stages of evolution. As part of the remotest island chain on earth, Hawai'i's plant and animal life has evolved uniquely and is characterized by limited biodiversity. Lying amidst one of the most regular wind systems in the world, it has remarkably varying climate. The island generates its own weather.

Nevertheless, impacts of remote regions are felt. Dr. Schroeder discussed the history and interpretation of the Mauna Loa Observatory CO_2 time series to emphasize interactions among ocean, atmosphere, land, biology and humankind which must be accounted for in this "most significant geophysical time series." He also discussed local impacts of the geology (volcanoes) on Hilo weather.

I'd like to begin today with your own experience and build the Hawai'ian Earth System ideas around that, showing how the land, sea and air work together. We had seven inches of rain in twelve hours last night. You notice the awnings, the walkways...people have adapted to the conditions of the Earth system. The average rainfall at the airport is 133 inches annually. I am primarily a meteorologist, but I will begin with a little geology. Then I'll discuss certain weather patterns on the island and describe some ongoing efforts at Mauna Loa observatory.

First, I am going to briefly talk about the regional characteristics. Most of you have heard about hot spots, as described in the journal *Nature*. Most scientists have heard about how hot spots are detected and tracked. It's called ***trajectory analysis*** (tracing things back to their origins). Some colleagues at the university have applied this by taking the known distribution of sea mounts and the best guess of what the crustal plate motions have been, and working backwards. They take every seamount and track it back in history. The idea is that if these trajectories intersect, that should be a geologic hot spot. The key is determining how the plate motions go backward, because it doesn't look like the current distribution. If we focus in closely on the north Pacific, we see that the main intersection of these tracks is right on the island of Hawai'i. We have always said Hawai'i is where the hot spot currently is, the place where magma is emerging to form new crust, either under the sea or on the surface.



Ages (in millions of years) for basalt in the Hawai'ian island chain.

That brings us to how our island chain was produced. I'm going to talk mostly about the Big Island because most of the natural phenomena are best represented here. We have a Big Island comprised of basically five volcanos with a sixth volcano called Ninole, now buried down on the flank of Mauna Loa. If you were to read *Volcanoes in the Sea* by MacDonald, Abbott and Peterson (1983), you would find there was a seventh mountain, Kulani, which disappeared. Apparently the site of Kulani probably is not a separate vent.

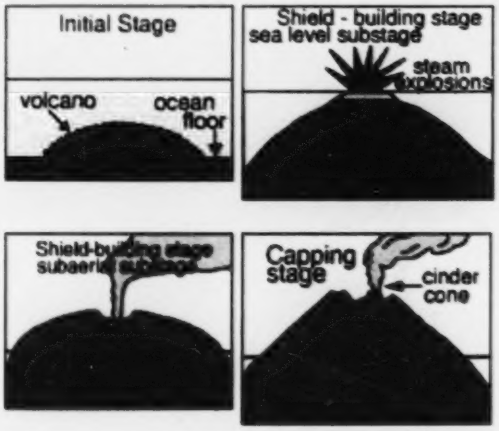
The five major peaks on the Big Island are as follows:

- Mauna Loa, the most massive mountain on earth, over four kilometers high, last erupted in 1984.
- Hualalai, one of the better kept secrets, over eight thousand feet, last erupted in 1801. It erupted after the time of Captain Cook, and most of Kona airport sits on the lava flows. A heavy population has built up along those slopes.
- Kilauea, which is erupting now and continuously since 1983.
- Mauna Kea, most famous now for the observatory, is another peak more than four kilometers high. It apparently had an eruption about 4500 years ago.
- We have the Kohala Mountains as they are called, that are basically eroded peaks. This is actually one

old volcano which is probably five hundred thousand years old.

- Then this mystery one, Ninole, which was active about 100 to 500 thousand years ago, based on potassium-argon dating.

Volcanoes go through "life stages" here. First we have submarine shields; Loihi is an example. Shield eruptions may finally break through the water surface as islands. Volcanoes in the socalled shield building stage are Mauna Loa and Kilauea. Next is the post-caldera stage. Kohala fits this category. My colleagues may decide that calderas are not really necessarily part of the cycle, because they come and go. Different geologists have different opinions about Hualalai; some have determined that Hualalai has probably never had a caldera per se.


Initial Stage
volcano
ocean floor
Shield - building stage sea level substage
steam explosions
Shield-building stage subaerial substage
Capping stage
cinder cone

Those are the five mountains on the Big Island, and Loihi is submerged on the flank. From space shuttle views you can see Mauna Loa, Mauna Kea, Hualalai and Kohala. Kilauea barely shows up because it's such a gradual feature. The interesting thing from the meteorological viewpoint (and from a number of viewpoints) and is that they are various ages, various shapes, and various elevations. I will get back to that.

I want to talk briefly about the newest mountain because there are some exciting things going on at Loihi. This is the most recent detailed sidescan sonar topography of Loihi done in 3 dimensions. Loihi comes to within about a thousand meters of sea level, and its roots are so deep we can't see them with our submersibles. We don't go deep enough.

In 1996, there was a major seismic crisis on Loihi—a major event in history, and we were able to get a rapid response mission out there with NSF and NOAA support through our undersea research program. We found some tremendous structural changes that have occurred. For example, a number of hydrothermal systems have been sighted over the years on Loihi. "Pele's vents," was previously a rich hydrothermal field. As of August, 1996, Pele's vents are now Pele's pit because a giant pit crater developed.

Depth (m)
2035
4120

Bathymetric 3-D image of Loihi seamount, from Internet site, University of Hawai'i.

Oceanographic sampling has detected in the water column some evidence of magmatic materials and gases that have been injected into the water column somewhere east of the island. We think there's been an eruption at low along the rift, but we can't dive deep enough. *Pisces V*, which is the Hawai'i Undersea Research submersible, goes to two kilometers and we would probably need to be about four kilometers deep to find it. So, we're debating, did it erupt or not? First of all, how many people knew what a seamount would look like? It's basically a pile of rubble with a bunch of pillows stacked on top. Not surprising that it's somewhat unstable. What we find now is the south side is dark–that is the chasm which drops a few hundred meters, where there's obviously been a big slump. Now, with Loihi being more than a thousand meters down, it is a problem to get very good observations. We are trying to do something about that. We are going to be, in the next few months, hopefully, using the *Pisces V*. *Pisces V* can deploy HUGO (the Hawai'i Undersea Geo Observatory). It is actually one of the world's biggest junction boxes, and it will sit on the slope of Loihi. The problem we had in 1996 was the target site where they were going to put HUGO disappeared! The geologist in charge simply didn't realize how treacherous the slopes were there; this was a most precarious place to put an instrument.

Thus a giant junction box is going to be sitting on the flank of Loihi and linked by an undersea cable to the old abandoned sugar port of Honuapo, which is just down on the southeast flank of Mauna Loa. A hundred years ago boats would come up to an old pier there and pick up products from the sugar mills nearby. There's an abandoned mill right across the street from it. We have turned that into a base station, so any kind of instrument platform that you want to put onto Loihi (a major engineering feat by the way because, at a thousand meters, everything is hard to do) can be hooked into that junction box and basically telemeter your data through that line to the shore. The NSF has spent about a million dollars on HUGO so far. It's expensive going there to put it underwater.

Loihi is one of the new exciting things. Of course, since it is a thousand meters down at the current rate of growth, its going to be a few lifetimes before we ever see it at the surface. Philosophically, whether people will be around to see it will depend on how our society functions!

Now I want to get into some things about the mountains and their impact on island weather, so you can get a feeling for what goes on around the island. Also, I want to talk about Mauna Loa Observatory.

Look back at the first map, and at the chart below. The Big Island makes up about 60 percent of the state's area. The older islands are more eroded, and the mountains are getting worn down. We have a variety of mountains at different heights. What makes this interesting is that when the moving air meets these mountains, very different reactions occur depending on the kind of mountain. (This is from a book of which I am an author, *Prevailing Trade Winds—Climate and Weather of Hawai'i*).

As you learned in your basic earth science or geography course, air rises at the equator, subsides in the subtropical "horse" latitudes at 30°, and the winds returning at the surface to the equator are called the Trade Winds. Hawai'i sits in the middle of the Trades. In the summer, this is the typical pressure distribution around the Pacific and the islands will be sitting right in a very steady regular flow, the second most reliable wind system on the planet. [The most reliable wind system would be the southeast Trades of the south Pacific.] Ninety percent of the month of July, the winds at Honolulu Airport are from northeast. That's very consistent. In the winter its about 50% and on the annual average, it's about 70%. So this is our dominant system. Our whole geography is windward and leeward, based on the Trade Winds.

Let's look at the Trade winds' flow around the island. Pictures from the space shuttle Challenger clearly illustrate fluid flow around the islands, similar to a rock in the stream. One of the things you may have noted (with the exception of yesterday), is that normally the clouds and the Trade winds are capped and held at a fairly standard level. Special interactions occur as this rock stands up in the Trade winds.

Let's focus in on the nature of the Trade winds. Some work by Joanne Simpson, almost forty years ago, describes what a typical section of air looks like if you come along a cross section. If you were flying from San Francisco at 7000 feet, you would find air moving down from California towards Hawai'i, being heated from below. There is a stable sinking air associated with that high aloft, and it's stronger near San Francisco. So when you fly out of San Francisco, you often fly through it in the first five hundred feet (that's the top of the cloud layer as you come out of San Francisco airport). And if you move downstream towards Hawai'i it gets thicker and thicker, but there's still a cap. To show how dramatic it is, there is a discontinuity in both temperature and humidity. The relative humidity drops precipitously. As a matter of fact, in 1840 when Charles Wilkes led a U.S. expedition on the first ascent of Mauna Loa, he took his dew point hygrometer up there, but could detect no moisture whatsoever because it was so dry. Along

Land Area and Maximum Elevation of Principal Hawai'ian Islands

Island	**Area: km²**	**Area: mi²**	**Peak Elevation: m**	**Peak Elevation: ft**
Hawai'i	10453	4038	4206	13796
Maui	1885	728	3056	10023
O'ahu	1573	608	1232	4040
Kaua'i	1432	553	1598	5240
Moloka'i	676	261	1515	4970
Lana'i	361	140	1027	3370
Ni'ihau	189	73	391	1281
Kaho'olawe	116	45	450	1477

with that drying, there is a warming due to the sinking of air. This is the adiabatic compression. If you use the right wave length of radio waves, the temperature and dew point discontinuity leads to a density difference, a refractive index difference, that shows up on a vertically pointing radar. The cap becomes "visible" as what we call the Trade winds inversion.

Other features of island weather are Trade winds showers. They develop up to about 2 kilometers, but they do not penetrate the inversion. What drives that inversion is the sinking motion associated with that normal high pressure system. Typically the clouds should only be 7000 feet. So, what happened last night? An upper level weather system came by that shifted the pattern of motion aloft to up instead of down, so the inversion disappeared. And, boom, there went the lid for that light show last night. Seventy percent of the year, the pattern is the same. Occasionally a storm occurs as it did last night.

Altitude and wind direction lead to some very dramatic climate variations. I will just focus on the island of Hawai'i. The mean annual rainfall for the island of Hawai'i, based on all data available over about a hundred-year record, is six thousand millimeters or 250 inches a year above Hilo. The summits, however, are quite dry. In fact, some areas get less rain than what we estimate for the open oceans around here. So we have spectacular differences there. The island is sucking water out of the atmosphere, we might say. The southeast flank of Mauna Loa gets a unique rainfall maximum also, predominantly in the summer. The Kona coast has its own little rainfall maximum. The key thing I want to note on all those is that they're on the slopes of mountains that penetrate the inversion. North Kohala has more than a four thousand millimeter maximum right on top of the mountain. That's a five thousand foot mountain–it's below the inversion. So we get different rainfall distributions, which show up in vegetation and plant life differences on each of the mountains depending on their dimensions. The ultimate example of a mountain that does not penetrate the inversion is Kauai. The peak rainfall is 11,000 millimeters a year; the *Guinness Book of Records* accepts that now as the wettest spot on earth. This is a sheer cliff facing the prevailing Trade winds. But the way that island is oriented, any wind direction results in showers on the summit.

To give an idea now of how big an impact the mountains have, think about this. The prevailing direction of the Trade winds is northeast or east northeast. The prevailing wind direction at the Hilo airport is west southwest. Now, how could that be? Well, above 8000 feet, Mauna Loa is just big bare rock. It has tremendous capacity for absorbing sunlight during the day and cooling off at night by radiation into that dry air above the inversion. Every night the wind comes down off the slopes—a mountain breeze which moves into Hilo–and the prevailing direction will be west southwest.

Because of the reproducibility of the weather patterns here, it is a great place to do investigations on very fundamental problems. In 1990 a study was done on the rain band that forms out in the bay at night. In forty-two days in 1990, we had one hundred rain bands to sample in Hilo Bay. That's very reproducible! This shows that at night the island is basically breathing out against the Trade winds. The downwind flow is so strong that it displaces the Trade, and it is very regular, it happens every night. If you recall, the Trade winds blow only 70 percent of the time. The prevailing wind is the one most frequently observed; at Hilo that wind is downslope at night.

As for the daytime, there's one interesting feature showing how the local effects dominate. And that is, along the Kona coast. During the summer, a sea breeze blows every day. That air converges with Trades that kind of sneak around Mauna Loa to produce an afternoon cloud up on the slope, producing rainfall on the Kona coast on the leeward side. That's how you get that 100 inches per year on that side. On the Kona coast is the only place in the state of Hawai'i where the rainy season is summer (now). The rest of the state has its rainy season in winter, but that is due to local effect. The person who discovered that was Luna Leopold who was fairly famous as a geomorphologist, an American professor emeritus at Berkeley. In the 1940's, he worked for the Hawai'i Pineapple Research Institute doing weather research and did some fundamental work on island meteorology.

One of the most outstanding factors that is produced by the regular interactions of the mountains and the Trade winds are reproducible weather patterns. For example, an analysis of nine to fourteen years of daily rainfall records for 24 rain gauges on the island of Hawai'i shows the clear diurnal cycle. In a nine-year period in the month of June, it never rained on the Kona side at 2000 feet elevation between the hours of 9 and 10 AM. Kona has an afternoon rainfall maximum associated with that sea breeze. In Hilo, the maximum rainfall occurs around midnight to 2 AM. A simple sine curve explains 90 percent of the variance of rainfall frequencies on the diurnal cycle. It's that regular. Minimum is normally around 1 PM. It's very much like clockwork and it shows up in the weather forecast! The first refuge of the forecaster here is climatology. So Hilo's forecast will be "showers at night and clearing in the midday." That is the climatological forecast, a prediction based on the historical record.

A diagram of frequency of occurrence of rainfall on the Kona (west) coast of Hawai'i is going to be basically like this: essentially nothing in the morning; then around midday, a dramatic rise in the amount and frequency of precipitation. As showers develop up on the slopes, at night they just move down to the shore, so that a station farther down slope would have less rain and a later rainfall peak. On the Hilo side, it is even easier to predict–just a midnight to midnight sine wave, with the precipitation at night. If you go along the Hilo coast, there are 5 rain gauges that all show exactly the same pattern. On the windward side of Haleakala in Maui, the ten thousand foot mountain shows a similar pattern, all forced by the islands. So each island makes it own weather. You can basically choose what kind of weather you want. If you like rain at night, come to Hilo. For rain in the afternoon, go to Kona.

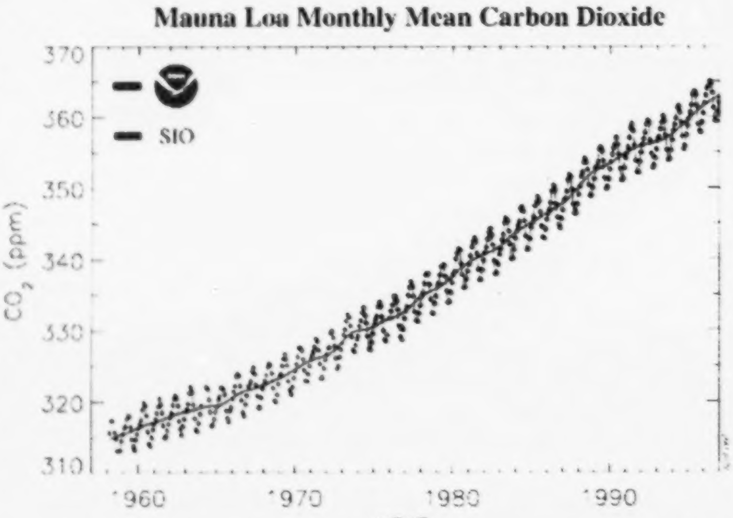
The rain in Kona has a special application. Perhaps you have had gourmet Kona coffee. Before the age of fertilizers, coffee was grown as a shrub in a canopy of other trees; it would have suffered extremely from direct sun damage. But on the Kona coast, because there are afternoon clouds every day, the coffee could grow without any forest canopy. So prior to the age of fertilizers, the only place coffee survived in plantations was on the Kona coast. Now with fertilizers, coffee can be grown everywhere. But Kona coffee was a direct result of the local weather patterns.

There are others who can tell you more about the biosphere in Hawai'i. I will mention a brief example of fauna and that is a unique spider that lives on the summit of Mauna Kea. Mauna Kea is an alpine desert according to climate classification. The mystery is how this spider survives up there. Remarkably, the afternoon upslope wind brings insects up, and so basically, the food is brought to the spider by the local circulation!

On your field trip to the volcano, you heard from the biologist about blind cave creatures that have grown in the lava tubes. We have some interesting evolutionary stories. One of the major issues in Hawai'i is biodiversity. The islands have bio-nondiversity, a very limited number of species. But those organisms have done some interesting evolutionary tricks. It was not easy for new organisms to get here until the age of jet aircraft and ships or Polynesians.

I want to discuss one of the better kept secrets on the island, the Mauna Loa observatory, which takes exact advantage of the locations here. Mauna Kea has observatories that almost everybody has heard of. The dry air above the Trade wind inversion is good for infrared and other types of astronomy. The first Mauna Loa observatory was created in 1949 right at the summit. It was abandoned, then resurrected in 1957. Being at 3.5 km puts the Observatory above the polluted boundary layer of the atmosphere, so supposedly measurements taken there are pristine remote atmospheric samples.

Almost anybody can identify the Mauna Loa carbon dioxide curve, dating back to 1957, started by Charles Keeling of the Scripps Institution of Oceanography. He started doing measurements here at Mauna Loa as part of the International Geophysical Year, 1957. The IGY was famous for a number of achievements. One was the establishment of the Mauna Loa record and the other was the fact that it was an El Niño event. Everything went crazy in the equatorial Pacific for the IGY. That



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography. Data since May 1974 are from the National Oceanic and Atmospheric Administration. A long-term trend curve is fitted to the monthly mean values. Principal investigators: Pieter Tans, NOAA/CMDL, Carbon Cycle Group, Boulder, Colorado, (303) 497-6678, ptans@cmdl.noaa.gov, and Charles D. Keeling, SIO, La Jolla, California, (619) 534-6001.

got people interested in the problem and led to the whole generation of research on El Niño and climate variations. The Mauna Loa record of CO_2 shows an annual cycle basically related to the activity of green plants in the northern hemisphere. It shows a trend upward. It also shows some little flat spots that correspond to major El Niño Southern Oscillations. Apparently when you upset the circulation of the equatorial oceans and upset the thermal structure, you also upset the ability of the oceans to take up dissolved or non-dissolved carbon dioxide. So you see a drawdown of CO_2 for a while during El Niño events. The interruption of the trend in the early '90s reflects a long-lived El Niño.

The Mauna Loa Observatory has a precarious existence. It is right on the shoulder of an active volcano. Having that volcano nearby introduces a problem: the wind direction has two components. One is basically a southerly wind coming right out of the volcano caldera. It turns out there's carbon dioxide present. The Mauna Loa recording after an eruption is charged with CO_2. So one of the problems at the observatory is that they have to filter the data very carefully. They even pave the road well up there to keep dust down, and they have a limit on how close cars can get. Since the instruments are so sensitive, automobile exhaust is a problem.

Now, with the clean air backgrounds at a site like that, the importance of course is long records. Those who have followed this know they've had very interesting history keeping that observatory going. Politically, there's not much funding available for routine observation. It is a major fight, but perhaps the war has been won now. Some of the interesting results coming out of there include sampling of all kinds of atmospheric trace gasses, including the dreaded CFC_{11}, the spray can output. The trace indicates that the Montreal protocols are working: concentrations are actually leveling off or dropping a little. CFC_{12} hasn't quite stabilized yet, but there's hope. That compound is just a little slower to settle down.

The replacements for the chlorofluorocarbons are now showing up in the monitoring being done at Mauna Loa. The observatory also runs vertical pointing lasers to pick up stratospheric clouds from volcanic eruptions. Two big spikes recently are El Chichon in 1982 and Pinatubo in 1991. In long records, you can also check the interference with sunlight coming through the atmosphere. You'll get the inverse signal from the Lidar. This is back far enough to pick up Agung in Bali (1964) which also produced a small effect. From Mauna Loa, we can also contribute data to Global Monitoring for Climatic Change, which has sites in Beryl, Alaska; Mauna Loa; Pago Pago; American Samoa, and the South Pole.

The disturbing thing we are now finding at Mauna Loa is evidence of air pollution. Besides the Asian dust storms that we see every spring, we are now seeing diesel exhaust products, apparently of Asian origin, and probably Chinese. Perhaps the next big impact on the atmosphere is going to be the industrialization of China. We can see it from this remote background. This remote background depends on the unique combination of this location, the size of the mountain, the unique nature of the Trade wind interacting to allow that site to flourish.

This summarizes the points I was going to discuss today—origin of the mountains, what they do to the weather, and one of most important by-products of these Earth system interactions: the establishment and maintenance of facilities such as Mauna Loa.

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School of Ocean and Earth Science and Technology, University of Hawai'i internet site *(http://www.soest.hawaii.edu/HURL/hurl_research.html and http://www.soest.hawaii.edu/HURL/images/loihi_3d.gif)*

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Climate Histories from High Temporal Resolution Ice Cores–Changing Paradigms

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Introduced by John Carpenter, University of South Carolina

Abstract. Annual to decadal scale paleoenvironmental records obtained from ice cores at carefully selected polar and non-polar sites provide unique glimpses of past atmospheric conditions including its temperature, chemical composition and dustiness as well as the local history of net accumulation. Non-polar ice core records complement polar histories by providing information about climatic changes which directly and significantly affect human activities such as fluctuations in the intensity, timing and duration of both the Asian monsoon and the El Niño-Southern Oscillation (ENSO). This paper presents (1) the decadal averages of $\partial^{18}O$ (based upon annually resolved data) for the last 500 to 800 years that include the Little Ice Age; (2) evidence of a strong positive link between accumulation over western China and that in the Peruvian Andes; (3) evidence of similar temperature trends (inferred from $\partial^{18}O$) in the Peruvian Andes, western Tibet, and over the East Antarctic Plateau during the latter half of the Holocene; and (4) a tropical ice core $\partial^{18}O$ record which reveals a Late Glacial Stage cooling of 8°C at high elevations in the tropics. Documenting variability in our environment becomes more urgent as the need arises to forecast the range of future climate variability under a warmer Earth scenario. These unique archives provide the high temporal resolution, multi-faceted records essential for a global perspective of past climate variability. When integrated with other proxy records, they challenge our constructs of how the Earth System operates and provide the time perspective essential for assessing 20th century climate variability.

[Dr. Thompson indicated that the Internet site for the Byrd Polar Research Center *(http://www-bprc.mps.ohio-state.edu)* could provide further information about the *The Role of the Polar Region in Global Change*, a Chautauqua Workshop conducted for extensive study of the polar environment. The page labeled Icecore will carry updates of material presented here.]

A nighttime image of South America shows the inhabited portions of South America as lighted areas. It also illustrates a large number of fires associated with biomass burning in the Amazon area. I want to open my presentation with this as an example of what I think is becoming a fact: human kind is probably becoming the most important geomorphic agent on the surface of the Earth today.

At no time in human history have human beings had a greater impact than in the 20th century. All the major biogeochemical cycles, those involving water and soil and nutrients, have now been disturbed in some way. One example of this is the anticipated large-scale warming that we may experience at some point in the Earth's future in response to the emission of greenhouse gases. We also know that the climate system is naturally very variable and that these human-induced changes are superimposed upon this natural background. It may take some time for the anthropogenic component to become evident, or in other words, for it to rise above the background of natural climate variability.

What I want to discuss with you today is the contribution of the Earth's frozen archives to our understanding of the Earth system. Ice caps and ice sheets contribute in two ways. First, they reveal the history of the Earth's climate system. We know that the concentration of CO_2 in the pre-anthropogenic atmosphere was about 280 parts per million, and we know this from the records contained in polar ice cores.

Second, if we observe the ice systems on the Earth today we find that in the tropics and subtopics, most of the major ice fields are diminishing. This is a clear sign that there is something somewhat different about the boundary conditions of the Earth's system in the 20th century. This leads to the title of my talk: *Climate Histories From High Resolution Ice Cores–Changing Paradigms*. The Quelccaya ice cap in the southern Andes of Peru has layers, each of which marks one year's precipitation and the dust bands deposited during the dry season. Thus, when we come along with a drill, and we take an ice core through that stratigraphic sequence, we can extract an annually resolved paleo climate record. The ice core contains a variety of chemical and physical constituents that tell us about the past climate and environment of the Earth.

Many types of environmental data can be extracted from an ice core. For example, we can estimate changes in the Earth's temperature using a measurement called the oxygen isotopic ratio and another called the deuterium to hydrogen ratio. These tell us something about the temperature in the Earth's atmosphere at the time that the precipitation condensed. We can measure a variety of chemical constituents. For example, chlorine concentrations tell us about the abundance of sea salt in the air, while sulfate signals the emissions from volcanoes. We can measure heavy metals such as lead, and other scientists have tracked the human development of smelting from Greenland ice core records. When the cores contain some identifiable annual marker, such as these annual layers shown here in the Guliya ice cap in China, we can estimate the amount of ice that accumulated in that specific year. So, we can tell you something about how much precipitation fell at a particular drill site. We also measure the concentration and size distribution of the dust in the cores, which reflects the history of atmospheric dustiness. Pollen trapped in the ice tells us about the vegetation and changes in the local environment. As I said, the excess sulfate (that not originating from the ocean) allows us to reconstruct volcanic history. In more recent ice we also have sulfate contributed by the burning of coal, particularly high sulfur coal. Another indicator of anthropogenic activity is the recent increase in nitrate which is derived from the application of fertilizer in the northern hemisphere. There has been a tremendous increase of anthropogenic nitrate and sulfate since about 1850.

Because ice caps and glaciers are found in many locations on Earth we can look at different components of the Earth system if we take cores at many locations.

Figure 1

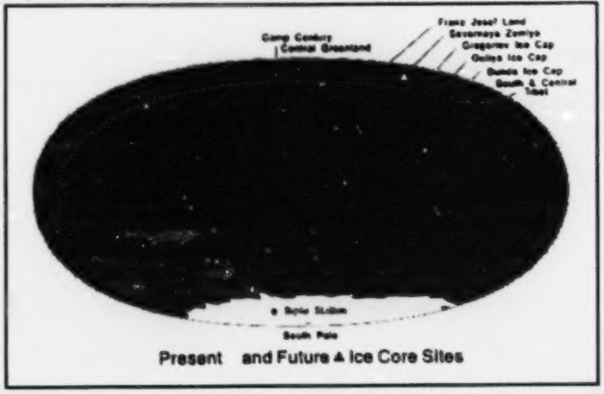


Figure 1 highlights the various places where our research group at Ohio State has had successful ice core retrieval projects as well as those sites where we plan to drill in the future.

Today, I'm just going to focus on a few projects. If you are intrigued by what you hear and if you think some of the materials that I present can be used in your class, I again invite you to look at our web page, go to the ice core group because we have some really nice GIF files that are downloadable.

Today, I'm going to talk about two projects in South America, the Quelccaya and Huascarán ice fields, and we will some see some examples from China as well as one field program in Antarctica.

First, let's start with the Quelccaya ice cap located at 18,600 feet in the southern Andes of Peru. Quelccaya sits on a very flat ignimbrite flow and covers 60 square kilometers. Although Quelccaya is located very close to the Pacific, almost all the moisture that falls on the Andean ice fields comes from the Atlantic Ocean. The water vapor passes over the Amazon Basin, and as the air is forced up over the Andes, the snow is deposited on the summit ice fields. You can imagine that taking drilling systems with heavy cables and drums of fuel to 18,000 to 22,000 feet, the range at which we are working, is quite difficult. We must use very light drilling systems, and where it's possible we also use solar power. An array of sixty solar panels that produced two kilowatts of power allowed us to drill two ice cores to bedrock through the 160-meter thick ice cap.

Figure 2

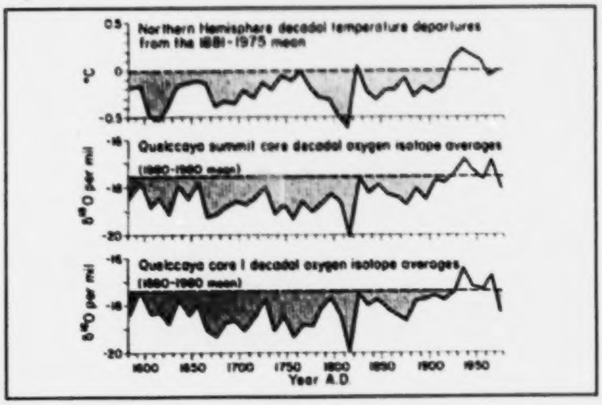
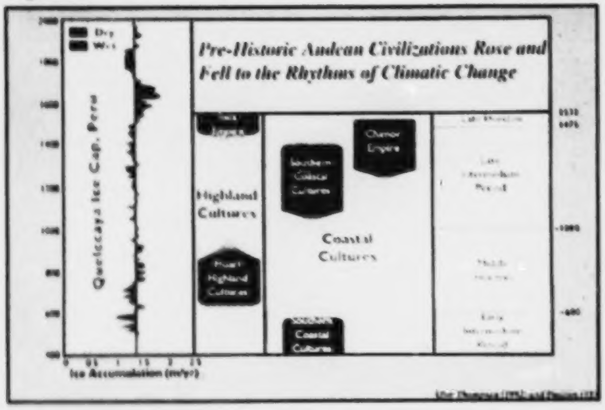


Figure 2 illustrates the oxygen isotopic ratio, our proxy for temperature. The bottom two diagrams show the oxygen isotopic ratio for two ice cores. The upper curve is the reconstructed Northern Hemisphere temperature record. There is great similarity between the oxygen isotopic records and air temperature. We reported these data in *Science*[1]. They provide the first evi-

Figure 3



dence in the tropics for the Little Ice Age cool stage, or what we really like to call the most recent neoglacial stage from about 1450 to about 1880 A.D. You can see that the isotopic data track the meteorological data very nicely. I specifically want to point out the decade between 1810 and 1820, which is isotopically depleted, implying colder conditions. In fact, comparison with the Northern Hemisphere temperature record reveals that this decade, containing the eruption of Tambora, is the coldest decade on record. What we didn't know until we produced an excess sulfate record, this time from Antarctica, was that another volcano had erupted in 1809. This eruption does not appear in the historical records, but it was very explosive and emitted almost as much sulfate aerosol to the stratosphere as Tambora. This answered an interesting question that scientists had asked for quite a while, and that was, if Tambora was responsible for the cooling of the decade, why did the cooling begin several years before Tambora erupted? The answer is, there was another eruption. But without these ice core records we would not have known that.

I love working in both Antarctica and Greenland, but one of the nice things about working in the tropics is that you also have a human component, a long anthropological history to which you can tie ice core records. This gives us a glimpse of the relationship between human activities and the environment. One example of this is illustrated in Figure 3. On the left is a 1400-year record of net accumulation from the present to 400 A.D. The accumulation is plotted with respect to the mean line so we can see a dry period in the latter part of the Little Ice Age centered at about 1800, while there was a very wet period in the early part of the Little Ice Age. The shaded areas show periods of reduced and increased accumulation. On the right the diagram shows the rise and fall of the cultures in Peru. The development of the highland cultures is out of phase with the development of the coastal cultures. Now remember our ice core record comes from the highland area. Thus, the highland empires tended to flourish during moister conditions in the highlands. Note that a particular highland culture, or the evidence of it, diminishes in the archaeological records as the conditions in the highlands become dry, but then we see coastal cultures advancing. I think that what we see here is the natural human inclination to follow water. We see that regional changes in the hydrologic cycle will drive the human response.

Various areas in South America are affected by the El Niño Southern Oscillation (ENSO). We know that ENSO has global impacts. For example, very dry conditions dominate the eastern part of Australia. Monsoonal failures have been linked to ENSO. Of course, warm sea surface temperatures are associated with the flooding along the western coast of North America and down in the southeast, as well as with dry conditions in southern Peru. We were able to observe directly the effect of ENSO on the Quelccaya ice cap. During the 1982/83 ENSO event it received very little precipitation. By drilling ice cores, we can go back in time using the thickness of these annual layers to reconstruct the ENSO history of this region. The average precipitation on Quelccaya is little over a meter a year (that's in water equivalent and would be about three meters of snowfall a year). During the previous ENSO, 1976-77, accumulation dropped to about 0.8 meters. As we get a substantial reduction in accumulation on Quelccaya during ENSO, we can use the ice core record to extend William Quinn's ENSO record back beyond 1500 A.D.

Now I want to talk briefly about two projects that we have conducted on the Tibetan Plateau. It's probably the single most impressive feature on the Earth's surface. It has an average surface elevation in excess of 4500 meters and it's covered by many hundreds of thousands of square kilometers of ice fields. Dunde is a very large Tibetan Plateau ice cap with a nearly perfect dome shape. In 1987, we drilled three cores to bedrock.

Let me digress here for a moment. Essentially, what people always say to me is "how deep did you drill?" Often people will attempt to relate the thickness of the ice cap with the amount of time preserved there. In reality, there are three things that dictate how much time will be captured in an ice core. 1) Is the ice cap frozen to the bed? If it is not frozen to the bed, you will lose your record off the bottom by melting. 2) How thick is the ice cap? Obviously, all other things being equal, thicker is better. 3) The final important contributor is, how much precipitation does the area get every year? Fortunately, Dunde was frozen to the bed, has a beautiful dome shape, and received a nice accumulation of about 40 centimeters of water equivalent. Actually, when we did this project, we expected to get a record of maybe five or six thousand years. In fact, this record goes back forty thousand years.

Figure 4

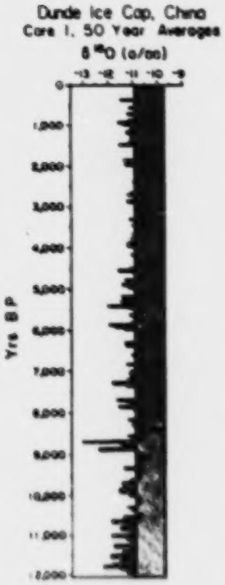


Figure 4 includes the last twelve thousand years of the Dunde record. This graph shows the oxygen isotope history where more negative values generally mean colder conditions and less negative means warmer. The data are plotted as 50-year averages and you can see the various periods of warmer and cooler conditions as you would expect. Here you see the end of the last major glacial stage, what we in the US call the Wisconsinan and the people in Europe call the Würm. Erroneously some people also call this period the last ice age, but in reality, it was just the last (or most recent) major glacial stage. The shaded area represents the isotopic value of the last fifty years, 1937 to 1987, and it is projected backward in time. This figure reveals that at no time in the 12,000-year history have we had a fifty-year period where isotopically inferred temperatures have been warmer. Let me make two comments. One is, ice cores are excellent in that they allow you to look back through time. That allows us to look at the 20th Century with a longer term perspective. The other thing that is interesting about this warmth of the 20th Century on the Tibetan plateau is that most of the climate models indicate that one of the first places you might expect evidence of anthropogenically induced warming is at high elevation in the interior of large continents. This record is from the Earth's largest continent, from one of the highest locations, and suggests that the 20th Century has been unusually warm.

Now I want to move all away across the Tibetan Plateau to the western side, to the western Kunlun Mountains to an ice cap called the Guliya ice cap which sits at more than 21,000 feet summit elevation. Guliya has a vertical margin much like that surrounding Quelccaya, which essentially means it's frozen to the bed. This means that you can anticipate a very long record. We call it a "polar-type" glacier even though this ice cap is located at 45 degrees north latitude. There is banding in the ice wall. This was a particularly hard project which required drilling day and night. The drilling was actually done under a dome tent so the drillers could have light at night.

Last month the results from these cores appeared in *Science*[2] so I will not elaborate on the details today. Let me show you how we can begin to piece these records together. The last 1000 years of accumulation from the Guliya ice cap, on the western side of the Tibetan plateau, can be compared to that from the Quelccaya ice cap in the southern part of Peru. In other words, we're able to make these linkages all away across the Pacific Basin, not on the annual time scale and not on the decadal time scale, but on multi-decadal to century time scales. We think that this linkage represents the large scale, multi-decadal scale linkage between the ENSO system and the monsoonal circulation system and we have a project in which we're investigating that in detail.

Every time we go somewhere and drill another ice core, its amazing how much more we learn about the Earth system. The one thing we as scientists must always be willing to do, is to modify our paradigm as we obtain more data. Some of our recent results from the Huascarán (Peru) core, along with some other evidence, have changed the way the scientists are thinking about the tropical climate system.

Huascarán is located in the northern Cordillera Blanca of Peru. It's a twin-peaked mountain and the drill site is in the col. Logistically it was a very difficult project. There was a crevasse that ultimately had to be traversed using ladders tied together. But, once you're up at the drill camp it is relatively flat. As Huascarán is located in the tropics, which has a distinct wet and dry season, we were able to use our solar-powered drill. The distinct wet and dry season puts within the ice core some seasonally varying chemical and physical parameters. The seasonal variation in nitrate, we believe, comes from the seasonal changes in the vegetation in the Amazon as it experiences the wet and dry seasons. By analyzing the cores in detail, each year can be picked out for some distance down the core. Obviously, at some depth, the layers become so thin, that we cannot discern them. Near the top, the annual layer is a meter thick. By the time we're down to about 1850, the layers are pressed closer together. Anyway, this shows you how we date the core.

What we did not expect from Huascarán was ice formed during the last major glacial stage. In the near basal ice we have very depleted (more negative) oxygen isotopic values along with a substantial reduction in the nitrate concentrations and much higher concentrations of dust. In all ice cores around the world that have been drilled and penetrated the Holocene—Wisconsinan boundary, scientists have found glacial stage ice is rich in dust and depleted in $\partial^{18}O$. The Huascarán cores contain the first evidence of the last glaciation in the tropics. That in itself was intriguing, but it was astounding to find late glacial-stage ice at nearly 20,000 feet in the northern Andes of Peru.

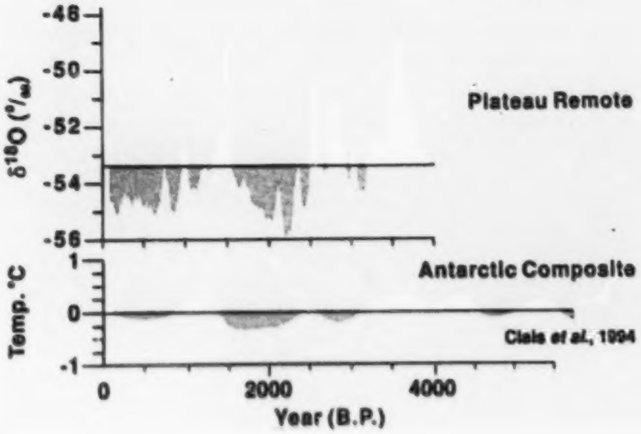
Let me explain what we think is the cause of that reduction in nitrate and the increase in dust. Comparison of the reconstructed vegetation pattern for 18,000 yr. B.P. in South America versus the vegetation patterns there today indicates that much of the Amazon Basin was formerly covered by savannah, that the tropical rainforest was significantly diminished, and much of the area was covered by loess and dune deposits. This is interpreted as a change in environment in South America and that is exactly what's been driving what we're seeing in our ice cores. These results were published in *Science*[3].

If we compare the dust and the oxygen isotopic ratios in Huascarán to those from the Byrd core (Antarctica) and Dye 3 in Greenland, they are all quite similar. In other words, in the tropics at 8 degrees south we have the same signals as the polar regions. What's even more interesting is that absolute value of the isotopic depletion in the Last Glacial Stage is on the order of seven parts per mil in Huascarán and in Antarctica it is six parts per mil and in Greenland it is seven parts per mil. In other words, we have labored under an incorrect paradigm for a number of years basically due to the results from CLIMAP. CLIMAP results were correct. They were simply incomplete. CLIMAP results indicated that the tropics really did not participate in the cooling of the last glacial stage. On the other hand, the ice core evidence indicate that the tropics did participate and experienced much colder conditions than has previously been thought. In other words, we have undergone a paradigm shift in the scientific community.

Now, I want to look at the Holocene, or more recent part of the record. You know that the Holocene has not gotten its due in the climate community. I think we've been fixated on what the Last Glacial Stage was like and what was the nature of the termination. In reality, the Holocene is that period in history when humans pretty much developed to their current stage. I think we should be interested in what the climate of that time was like on a regional basis. Until recently, the climate variability in the Holocene has been considered rather small and uninteresting. That really is not the case. There were very warm conditions of the early Holocene continuing until about 5000 years ago, and since that time the climate has cooled. Actually, the Holocene record in Peru is similar to what we see in the polar ice sheets.

In the next part of my talk I want to focus on climate variability of the last half of the Holocene. In 1987 we went out to a remote site on the east Antarctic Plateau, near a place that's called the Pole of Relative Inaccessibility. It's called that because it is the point, in the interior of the continent, that is the farthest from the coast in all directions. We had a six member team out at Plateau Remote for 21 days. Now I'll focus on the last 4000 years of the climate history of the east Antarctic Plateau. We're just using the oxygen isotope records (Figure 5). Between 2500 and 4000 years conditions were relatively warm, but they were interrupted by a very strong cool phase around 2000 years ago. This was followed by a warming, and in the last 1000 years, conditions have been relatively cool. If we put our record, Plateau Remote, against a composite six other Antarctic ice cores (none of which were analyzed in high resolution) we see that the Plateau Remote core reveals substantial variability over the last 4000 years.

Figure 5



Ciais *et al.*, 1994

I should have mentioned that we analyzed the Plateau Remote core such that we had an average of one sample per year. That's why it took us awhile to get the record out. Oftentimes, in these long cores, they may take one sample every meter. The problem with that approach is you lose a lot of the detail. Note the similarity of the records but that the Plateau Remote core provides so much more detail. The other cores tell us it was warmer here and cooler there, but we really don't get a good sense of the magnitude of the fluctuations. The record shows that between 2800 and 2200 yr. B.P., there is an isotopic ratios shift of about 5 parts per mil. And what did I tell you earlier? Between glacial and interglacial conditions in both the polar and tropical ice cores, this shift is on the order of about 6 parts per mil. We have about a 5 part per mil here in the latter part of the Holocene. The primary difference is that these shifts are very short lived. We're only talking about 1500 years. These records indicate much more short-term climate variability over Antarctica than we have recognized from previous (lower resolution) ice cores. The implication is that we have a fairly unstable climate. There's no stable baseline.

What I'm trying to demonstrate is, that even in a place like Antarctica, where most people think that climate will change very slowly, the climate variability can be large. It's easy for me to sell to you the idea that the climate over Tibet will change quickly or that the climate in the midwestern U.S. will change fairly quickly, but it is much harder for me to sell you the idea that, in the middle of a polar ice sheet the size of United States and Mexico combined, we get climate variations on the order of decades and large-scale swings on the order of centuries. These core results change the way we look at our climate system.

Finally I want to pull all this together. I've shown you the results from different ice core drilling projects and now I will show a collection of records in an attempt to put the 20th century within a 4000-year perspective. Now I am using numerous ice core records that are available, not just the work of the OSU research group. In Figure 6 we have plotted the last 4000 years in a sequence of diagrams. For example, we see some substantial differences between the Guliya and Dunde records which are located on opposite sides of the Tibetan Plateau. The cautionary note here is that you cannot use one single record to reconstruct a global record. You can't even use a single record to reconstruct a large regional record. You must have enough records to have good spatial coverage The second point I think is evident is that in the last few centuries, it's been warmer, except that we don't see much warming in the Antarctic. In this diagram, the Plateau Remote record is compared to that from Greenland and in the last 1000 years or so, conditions have been relatively cool in the polar regions. So there is little evidence (from the polar ice sheets) of 20th century warming.

Now, let me wrap up the talk by pointing out something that I said at the beginning and that is, we're losing ice on the planet. Now unfortunately, when I say that everyone starts thinking "Well, the Antarctic ice sheet is losing mass or that the Greenland ice sheet is losing mass. The bottom line is, we don't know what the Antarctic and Greenland ice sheets are doing because making mass balance estimates of such large ice sheets is a tremendous scientific undertaking. However, we do know that ice caps and glaciers around the world, outside of the polar regions, are disappearing at a very fast pace. Figure 7 shows the areas on the Earth where extensive ice fields exist and the colors indicate whether they are growing or retreating. We have retreat everywhere except one little spot up in Norway and Sweden and we have question marks over the polar ice sheet because we really don't know what's happening there. I haven't just drawn retreat dots indiscriminately. These are all based upon published literature.

Figure 7

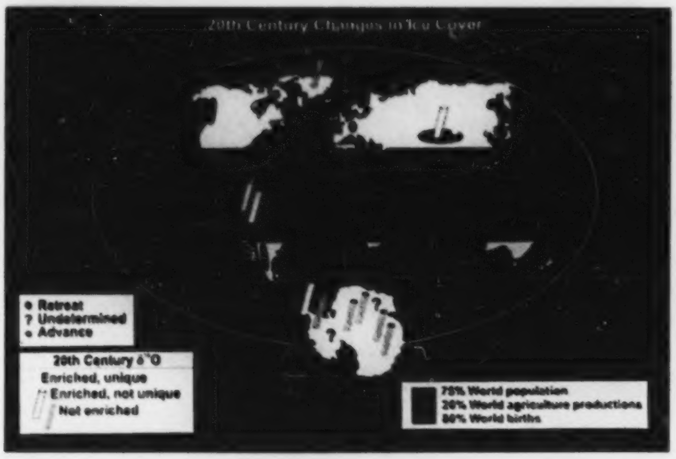
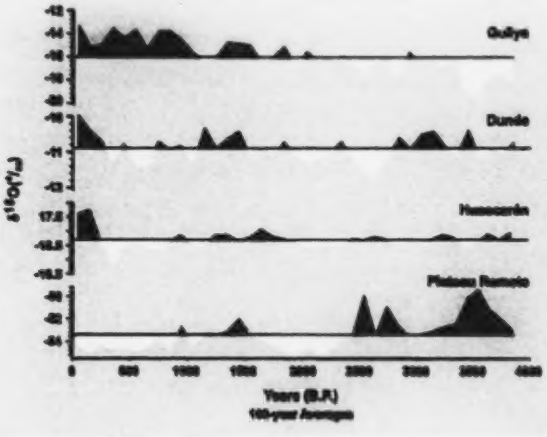


Figure 6



Recently, we've heard about the breakup of some of the ice shelves in the Antarctic. It is important to realize that these are the floating ice shelves such as the Larson and the Wordie. They don't contribute substantially to sea level change. They may, however, be indicative of some change in the environmental system. The Wordie, located on the western side of Antarctic Peninsula, has gone from 2000 square kilometers in 1936 to about 400 square kilometers in 1992. In 1989 we drilled an ice core on the highest part of the Antarctic Peninsula right in the middle between the tip and the base at a place called the Dyer Plateau. The oxygen isotopic record for the last 500 years shows that in the last forty years, it has been unusually warm. If we look back through the isotopic record, there are times of warmth, but these were not sustained over four to five decades as has been the persistent warming since 1940. Thus, our ice cores are recording the same changes that the British Antarctic Survey has observed by the mapping of the Wordie Ice Shelf—a very strong, persistent warming in the Antarctic Peninsula region since the 1940s.

To provide more striking evidence of the retreat of these ice fields, there is a little outlet glacier called Qori Kalis on the margin of the Quelccaya ice cap in Peru. This has been mapped since 1963. The rate of retreat is accelerating. Between about 1963-1978, it retreated at about four meters a year, but now Qori Kalis is retreating at 30 meters a year. This change is also recorded in the oxygen isotopic record on Quelccaya. In 1991, we went back and drilled another core at the same location as a 1976 core. The oxygen isotopic record which had beautifully preserved seasonality in 1976 had been virtually obliterated by 1991 because of the percolation of meltwater through the firn. Also, the average isotopic value is now two parts per mil more enriched, that is a change from -19.5 to -17.5. So again, the ice cores are telling us exactly what we observe in the environment today. That is, that we have substantial warming in this area and significant ice retreat. This is not happening just on Quelccaya. It's happening virtually on all tropical and subtropical ice fields.

If we look at the radiosonde data between 60 degrees north and 60 degrees south you see that the greatest warming is not occurring at the Earth's surface, but it is occurring between two to four kilometers in the atmosphere primarily in the subtopics. Remember that Quelccaya sits right in this region at about five kilometers elevation. The freezing level, or the zero degree isotherm, in the atmosphere is increasing in elevation, and since 1979 it has increased about four and one half meters per year. There's evidence of increased warming, not where we're measuring at the surface, but in the atmosphere. Many scientists think that what we're seeing here is an intensification of the hydrologic cycle. What's the most powerful greenhouse gas? I know, you like to trick your students and they will say carbon dioxide and you get to tell them, no, it's water vapor. An intensified hydrologic cycle will put more water vapor into the atmosphere. We think that's what we're seeing now. These ice fields are just our indicators of this change that's occurring in our system.

What factors are contributing to sea level rise? It's unknown how much Antarctica and Greenland are contributing, but we know that about 25% of it is due to the thermal expansion of the ocean due to the warmer temperatures of this century. About another 25% is due to melting of ice outside the polar regions.

To summarize…almost every ice covered area outside the polar regions is experiencing a reduction in ice cover. From the oxygen isotopic ratio we do not see strong evidence of 20th Century warming in the ice core records of the polar regions. Quelccaya and Dunde show that the 20th Century warming is unique and Huascarán and Guliya reveal that the 20th Century has been very warm but not uniquely warm. In other words, as is usual with science, you don't get a clear, single right answer. What we are dealing with is a very complex system. This is like asking 10 weather stations across the globe to tell us how the climate of the Earth has changed over that time period. What you are getting from the ice cores are long, detailed records that, of course, are from selective locations as ice doesn't occur everywhere. That's why we work in an integrated fashion with the other paleoclimatologists who collect sediments from the lakes, or histories from tree rings, and we work with the people who get high resolution ocean records. It's very much a community effort, a very integrated science.

Finally, as a geographer I've become more and more interested in the interaction between humankind and the environment. Let me just point out the regions of the Earth between 30 degrees north and 30 degrees south. That's fifty percent of Earth's surface area where about two-thirds of the people on Earth live. We all know that agriculturally it's a very depressed part of Earth. They only grow about twenty percent of the world's agricultural products. In other words, it is the part of the world that has a difficult time feeding itself. We know that water resources are quite an important issue for the tropics and the subtopics. And yet, what have I just shown you? I've shown you that the regions are losing their major water reservoirs. Thus, we are losing these permanent ice fields where water can be stored during the wet season and can be released during the dry season to produce hydroelectric power and provide fresh water. If you superimpose upon that, the third fact—that eighty percent of the people who will be added to the planet in the next century will be added to that area, you can see that, in reality, water will probably be a more legislated entity than oil in the next century.

So the ice core evidence shows very clearly that right now we have a substantial warming at high elevations in the tropic and subtopics. I can't tell you whether it's anthropogenically driven, but we can use the ice cores to look back through time to determine whether this 20th century warming is unique. We see that certainly in some places it is and in others it is not.

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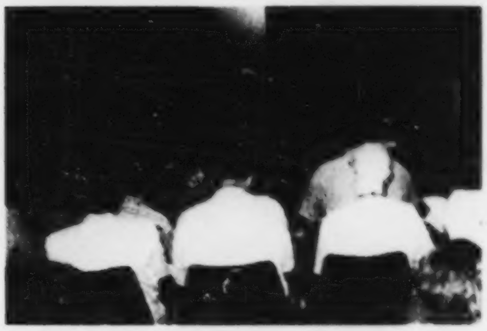
Interactive Poster Sessions

The primary portions of the conference were conducted in a unique format that allowed for a greater amount of interaction between the presenters and the participants than is typically available in the more standard format of 15–20 minute oral presentations. The format of "interactive poster sessions" seemed to provide the opportunity of more informal discussions, and also ameliorated communication concerns stemming from the variety of languages represented.

Interactive Poster Sessions were organized by the Program Committee based on topics of the submitted abstracts. One day's Theme was divided into two morning Sessions on college/university applications of the Theme, and two afternoon Sessions addressing its K–12 aspects. Within each Session, 10–12 poster presentations were assembled.

Interactive Poster Sessions had four major components that occurred within a half-day time period:



1. A short overview of the 10 to 12 presentations in the session was chaired by the session Coordinator. The Coordinator explained what the presentations had in common to group them into the session, and how the group would be divided for discussion groups in Step 4 below.

2. This was followed by an oral presentation by each of the poster session authors. Each presentation was limited to three minutes, just enough to inform the participants what would be available at each station.

3. Following the oral presentations was a period of about one hour in which each presenter was at her/his own poster. This allowed time for each presenter to talk individually or with small groups of the audience interested in the topic of the particular project or idea.

4. Concluding each theme session was a series of group discussions. The presenters and the audience for a particular theme session divided into three smaller groups for discussions on the posters in the session and other topics in geoscience education. Discussion groups were led by Moderators who developed summary reports from their respective sessions.

Theme I: Earth Systems/Science Programs

William H. Hoyt and Victor J. Mayer, Coordinators

Session IA: Academic, Government and Society Partnerships in Developing Science Literacy.

Edward D. Geary and Beverly T. Lynds, Moderators

Presentations in this session demonstrated how colleges and universities work with partners in government science and geoscience agencies and with professional societies, to develop approaches to science literacy. Included were descriptions of new courses and curricula for higher education, and programs for teacher enhancement at the K–12 level. Several examples of collaboration among diverse colleges and universities were identified and provided models adaptable to many world situations. Learning about the Earth as a system will increase opportunities for scientists' interaction as well as for educational collaboration in the next millennium.

An Environmental Studies Approach to Science Education in Grades 7–12.

George C. Flowers and Norma D. Felton, Department of Geology, Tulane University, New Orleans, LA 70118 USA.

Over the last five years, the Louisiana Systemic Initiatives Program (LaSIP) and Tulane University have trained over 120 teachers in grades 7–12 to use local environmental issues in reforming science education in their schools. LaSIP is an NSF-funded program to implement recommendations given in the AAAS report Project 2061 to increase scientific literacy among the general public. The workshop is based on the premise that for science education reform to be successful teachers need to have at their disposal the latest techniques in pedagogy plus a thorough grounding in science content. Training was provided in month-long summer workshops that brought together scientists working on interdisciplinary environmental problems and secondary school teachers. Content focused on environmental problems of special importance to the New Orleans area including: (1) coastal erosion and the destruction of wetland habitats; (2) toxicity of organic chemicals and heavy metals in plants and animals; (3) urban runoff and its effect on Lake Pontchartrain; (4) effects of hurricanes on estuaries; (5) freshwater diversion and dredging in estuaries; (6) waste-water treatment technologies; and (7) environmental impact of flood control.

The pedagogical component was taught by project staff with a special emphasis on modeling teaching methodology consistent with the science education reform movement. Topics covered in detail include cooperative learning, alternative assessment, inquiry-based learning, selective abandonment of detail, and in-depth coverage of concepts. One of the major thrusts of the Tulane-LaSIP project was cooperative learning, including Student Team Achievement Divisions (STAD), Teams-Games-Tournaments (TGT), Jigsaw II, Team Word Webbing, Think-Pair-Share, and simulations. The workshop also exposed participants to a variety of alternative assessments, including concept mapping, problem analysis, simulations, journals, position papers, and portfolios. Although some teachers have been more creative and experimental with their assessment techniques than others, the fact that every participant planned to use alternative assessments indicates a fundamental shift in philosophy. Teachers were required to develop a Site Action Plan, which details how each participant will seek to implement content and methodology learned in the workshop. Follow-up visits by the Site Coordinator, a master teacher who acts as liaison with the local school system, indicate widespread use and sharing of methods with their colleagues.

Making Connections.

Beverly T. Lynds, Project SkyMath, University Corporation for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000 USA.

The University Corporation for Atmospheric Research (UCAR) has developed a program, Project SkyMath, that integrates science, mathematics, and technology in a middle school (grades 5–8) mathematics module, Making Mathematical Connections: Using the Science and Language of Patterns to Explore Temperature, based on the content standards of the National Council of Teachers of Mathematics (NCTM). We have found that when used in a classroom, the SkyMath module has encouraged in-school teacher collaboration, connecting science, mathematics, and technology teachers. However, the most interesting connections UCAR is trying to establish are those between middle school teachers and university faculty. UCAR universities (62 research intensive universities having Ph.D. granting programs in the Atmospheric Sciences) are beginning a program to introduce the SkyMath module into their undergraduate courses that serve future middle school teachers. Earth Science Departments , interested in diversifying their offerings, have expressed interest in focusing one section on future K–12 teachers. The SkyMath module fits well into such a section and provides the future teachers with content that could be taken directly to the classroom. University scientists are also building connections to their education departments and are learning the teaching styles of the new pedagogy, implementing them in their undergraduate courses, and offering their scientific expertise as a backup to the SkyMath module. Faculty and undergraduate students are serving as resources to the local middle schools in a collaborative effort to support mathematics teachers in the implementation of the SkyMath module.

Following a similar pattern, the Universities affiliated with NASA's Minority University-Space Interdisciplinary Network (MU-SPIN) are connecting with local middle schools and encouraging them to introduce SkyMath into their curriculum. Seven minority universities have taken on the responsibility for building and maintaining Internet connectivity to minority institutions and predominantly minority-attended elementary and secondary schools in their areas. The SkyMath module provides math-content for the schools coming on-line and connects technology, science and mathematics in the curriculum.

The SkyMath module is freely available for downloading from the SkyMath homepage:

http://www.unidata.ucar.edu/staff/blynds/Skymath.html.

The Effectiveness of Constructivist Hands-On Instruction in a University Earth Science Course.

Ann Bykerk-Kauffman and Jane Kerlinger, Department of Geosciences, and Bonnie J. Johnson, California State University-Chico, Chico, CA 95929-0205 USA.

In order to test the effectiveness of constructivist teaching at the university level, we compared two sections of the same earth science course for prospective teachers. In the control (traditional) section, new concepts were introduced through lectures and videotapes; hands-on activities consisted primarily of skill-building exercises; faculty responded to student questions with explanations; grades were based exclusively on test scores; and students did no class presentations. In the experimental (constructivist) section, new concepts were introduced through guided-discovery hands-on activities; students engaged in small-group discussions of the meaning behind these activities and presented their interpretations to the class; faculty responded to student questions with leading questions; lectures served primarily to reinforce concepts previously encountered in lab; and only 30% of the course grade was based on test scores—the rest was based on attendance, short papers, a moon-observation project, and a final project in which students designed their own constructivist lessons and led the class through them.

We used pre- and post-course essay exams to test the students' understanding of six key topics (rock cycle, convection, seasons, phases of the moon, clouds, and wind). The two groups began the course with similarly low levels of understanding, but at the end of the course the experimental group displayed a better understanding of all six topics (on a 5-point scale, the experimental group averaged 2.8; the control group averaged 1.7). However, students' perceptions of the quality of their learning were reversed: on average, the students in the control group liked earth science better, were more excited about teaching it to children and felt more confident in their ability to do so.

Thus the constructivist teaching methods were more effective than were the traditional teaching methods. But many students felt uncomfortable in the constructivist classroom, probably because it was unfamiliar, required a tolerance for ambiguity, demanded a great deal of critical thinking and shifted authority from the instructor to the students—many students expressed a strong desire for "answers" even though the "answers" were provided by fellow students (during group presentations) and by the textbook. We now give students abundant encouragement and praise, and we require students to complete weekly homework assignments that guide them through the textbook readings. As a result, students now read the textbook more consistently, rarely express the need for "answers," and feel more confident and secure.

Earth System Science 1—Opportunities and Challenges in Multidisciplinary Earth Science Education.

John T. Snow, College of Geosciences, and Linda L. Wallace, Department of Botany and Microbiology, University of Oklahoma, 100 East Boyd Street, Suite 710, Norman, OK 73019 USA.

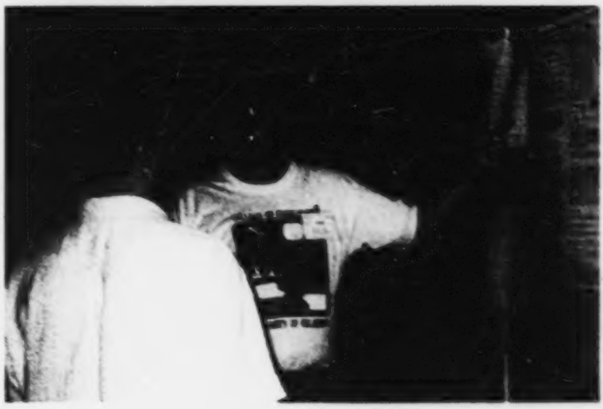
Today's university students, both those majoring in one of the traditional Earth science disciplines and those taking an Earth science course to meet a general education requirement, can benefit greatly from a "systems perspective" of the functioning of Planet Earth. Such a perspective provides a framework that aids in the development of student understanding by providing context to disciplinary knowledge and by integrating such knowledge with that from other disciplines. Tomorrow's social and political leaders need such a holistic understanding of Earth to address pressing environmental questions, while the next generation of Earth scientists and professional practitioners need it to participate in the increasingly cross-disciplinary nature of cutting-edge environmental research.

To provide such educational opportunities, the National Aeronautics and Space Administration, through the Universities Space Research Association, has undertaken a multi-year effort to nurture development of Earth System Science courses at universities nationwide. Efforts to offer such Earth System courses, include one at Purdue University, and, most recently, at The University of Oklahoma, under the sponsorship of this NASA/USRA initiative. In both cases, the offerings are a lower division introductory course and an upper division/beginning graduate course.

Experiences to date suggest that such courses are best team taught, with an Earth scientist and a Life scientist as team co-leaders. Team members should represent the full range of the Earth sciences—geology, meteorology, oceanography—and the Life Sciences, and should be committed to working together to provide a seamless presentation to the students. This last is both a challenge and an opportunity. There are surprising (valuable) differences in perspective about common subjects, for example, it is instructive to hear a geologist, a meteorologist, an oceanographer, and a biologist each describe the hydrologic cycle!

In the two offerings, extensive classroom and laboratory use is made of toy models constructed using STELLA (High Performance Systems) modeling software. These toy models have proven to be very effective in illustrating the dynamic, non-linear nature of the Earth System.

Student feedback obtained through examinations, surveys, and informal discussion indicates that they enjoy seeing interconnections between disciplines and learning where gaps exist in current knowledge. This points out to them areas in which they may become personally involved with their own studies in the future. Indeed, the students report being sufficiently intellectually stimulated that they want additional individual research opportunities built into the course structure.



Earth System Science 2—Laboratory Models for Exploring Earth's Climate System.

John T. Snow, College of Geosciences, John D. Ensworth, School of Meteorology, and Thomas A. Dewers, School of Geology and Geophysics, University of Oklahoma, 100 East Boyd Street., Suite 710, Norman, OK 73019 USA.

We report on the development and educational use of a suite of "toy" numerical models of major components of Earth's Climate System. The basic models address the 1) global hydrologic cycle, 2) the global carbon cycle, and 3) Earth's surface–atmosphere energy flow. These models have been developed for use by general education students in a lower–division undergraduate introductory course in Earth System Science. More advanced models include 1) a coupled energy balance/water cycle model, 2) a coupled carbon/oxygen cycle model, and 3) a realization of Watson and Lovelock's "Daisy World." These advanced models serve as demonstrations in the introductory course, and as prototypes for further development and extension in a capstone course in Earth Systems Science for upper division undergraduates and beginning graduate students in the geoscience, science, and engineering disciplines. These models have been realized using the STELLA (High Performance Systems) software as self–contained exercises intended to be completed during one or two three–hour laboratory periods. The approach has been to shift the role of the instructor from "learned sage" to "constructor of the learning environment" and "collaborator in exploration." The STELLA three–level structuring–mapping layer, modeling layer, programming layer–allows the novice user to focus on model operation and output, and not be overwhelmed with computational details. The ability to embed discussions within model elements provides "just–in–time" answers to student questions and promotes student understanding of model function and behavior. While even the advanced models have been, by necessity, simplified so that their behavior is not always realistic in terms of dynamics or final output, this is not necessarily "bad" in terms of pedagogy. Lower division undergraduates benefit from identifying nonphysical behavior and then determining what additional information would be needed and where it might fit into the model structure to make the simulations more realistic. For advanced students, this presents opportunities to "improve" the simulations by actually introducing modifications to model parameterizations and structure.

Student feedback regarding this instructional approach has been positive, albeit accompanied by many suggestions for improvement of the student–model interface and demands for greater interactivity. We are exploring accommodating the latter through STELLA's "flight simulator" mode of operation.

Nebraska Earth Science Education Network: Connecting University Resources and Earth Science Educators.

D.C. Gosselin, D.R. Mohlman, S.J. Meyer, M.A. Mesarch and B.P. Lang, Conservation and Survey Division, University of Nebraska-Lincoln, 113 NH, Lincoln, NE 68588-0517 USA.

A key component to any sustainable reform of science education will be improving communication between scientists and K–12 educators. Officially established in January 1993 by the Conservation and Survey Division, NESEN is a mechanism for encouraging cooperative partnerships and improving communication among earth scientists, science educators, and students. Through the efforts of many individuals, and particularly K–12 teachers on our steering committee, NESEN has expanded interest in earth science education across the state. K–12 earth science educators consider NESEN an important resource for earth science information. As of December 1996, NESEN membership was more than 370, a 33% increase from the previous year.

The word network implies the use of electronic media to link educators, but NESEN is about people working with people and using multiple strategies to improve earth science education. The strategies employed to deliver timely and relevant earth science information to the K– 12 community include:

1) participating in current professional development activities with emphasis on the Nebraska Association of Teachers of Science (NATS) annual meeting;
2) conducting summer workshops on earth science topics selected based on teacher interest surveys. These workshops integrate scientific expertise, hands-on experiences and the teacher's ability to translate information into lesson plans;
3) enhancing statewide communication by providing electronic connectivity, computers, and other logistical support for eight pilot site schools through a grant from NASA;
4) establishing video tape/CD-ROM lending library; and
5) making available materials and activities in a variety of formats that range from a lesson plan share-a-thon at NATS to a quarterly newsletter to the NESEN homepage *(http://nesen.unl.edu/nesen.html)*. In our continuing effort to be inclusive we published our third annual Resources Guide and Membership Directory to give those who do not have access to the

World Wide Web the opportunity to obtain information in a more traditional format.

To expand the diversity of our activities, especially in the area of climate/environmental variability and earth systems science, stronger working relationships have developed with the UNL's Department of Agricultural Meteorology and Teacher's College, as well as the U.S. Department of Energy's Great Plains Regional Center for Global Environmental Change. As a result, thirty schools have become involved with the Students and Teachers Exchanging Information and Ideas (STEDII) project, which has students actively collecting, interpreting, and exchanging weather data via the Internet.

Although the NESEN outreach concept has had an impact, there is more to be accomplished. The keys to our continued success will be improving communication with pre-service educators, promoting coevolving curriculum, and creating access to classroom-ready information and data that teachers and students can use to investigate their local earth systems.

Earth 2: An Earth Systems Science Course for Non-Science Majors at Penn State.

John R. Ousey, Jr., Penn State—Delaware County Campus, 25 Yearsley Mill Road, Media, PA 19063 USA.

Penn State University is the site of an NSF-funded Earth System Science Center. Early in the process of establishing the Center it was decided to develop an Earth Systems Science course oriented to the non-science major. The course is intended to provide these students with the flavor and excitement of this integrated approach to investigating earth processes. An interdepartmental course development committee agreed on basic themes for the course which have been modified over the past few years to suit the instructional experience encountered.

The course starts with global change topics and establishes the need for a multidisciplinary assessment of the problems. This is followed by an introduction to the systems approach where Lovelock's Daisyworld analogy is introduced along with other simplified models. In section two, the course focuses on the mechanics of the Earth System looking first at the driving force, then the circulatory system (air and water) responses. The role of Plate Tectonics, Ecosystems, and the Carbon Cycle interacting with the circulatory systems and each other concludes the section on mechanics.

The third section of the course shifts to the origin and evolution of the Earth System looking at climate regulation (long and short term feedback controls), and the evolution of life with subsequent impact on the atmosphere and oceans. This section concludes with the role of biodiversity in sustaining the stability of the Earth System.

The final section of the course delves into the future of the Earth System by referring back to the global change topics introduced at the beginning. Computer simulation is introduced to consider the effect of anthropogenic perturbations on the carbon cycle, ozone levels, and biodiversity. The course concludes with a consideration of possible futures and potential solutions to some of the problems.

The Deasy Geographics Lab in the Department of Geography of Penn State has developed many computer-based instructional materials for the course including static and animated graphics, and interactive modeling. These resources are available through the Internet at: *http://www.gis.psu.edu/Earth2HTML/E2Top.html*

Integrating Employment-Skills Training and Career Development into UK Geosciences Degree Courses.

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In the current, intensely-competitive graduate employment market, academic qualifications are becoming less important as a passport to a job and subsequent career. Employers are placing increased emphasis on recruiting graduates with well developed transferable skills such as communication, time management, teamwork, an innovative approach to problem solving and task and career management. Consequently, we as education providers have a duty to include training and opportunities for students to develop such competencies as part of degree curricula. For some academics, this represents a daunting and unwelcome change. The combination of employer requirements and this academic discomfort provided the perfect formula for the establishment of a national body designed to facilitate the smooth integration of transferable skills training and tailored career guidance and development into higher education (HE) curricula at UK Geosciences departments. Such a body has been established through provision of government funding and is called the "UK Earth Sciences Personal and Career Development Network." The network includes representatives from all 50 Earth Sciences HE departments in the UK, usually directors of teaching, curriculum developers, career advisors, and staff with interests in teaching and learning. The network has a three-layer structure: Layer 1 comprises the core partners, a team of Geoscientists from five UK Universities with a well-established track record of developing personal and career development initiatives and integrating them within the undergraduate curriculum. Layers 2 and 3 are represented, respectively, by individuals who are active in personal and career development largely from interest and those who are interested but have little or no experience. The network aims are:

- to establish and maintain a national forum dedicated to the discussion and dissemination of best practice in the field of personal and career development in the Earth Sciences;
- to develop appropriate mechanisms to ensure the long term integration of personal and career development within the curriculum.

  One of the first major tasks of the network was to complete an audit of national personal and career development activities in the Earth Sciences and compile a portfolio which could be disseminated for use by any HE department.

This presentation detailed:

- The "top-ten" transferable skills that Geosciences educators, careers advisors and employers consider to be an essential part of a graduate's profile and hence an essential ingredient in any undergraduate training;
- The audit results illustrating mechanisms used by HE departments to integrate personal and career development into the curriculum;
- An evaluation of how these results have been used in curriculum development by other institutions.

The future aims and scope of the network were detailed and an analysis of the fundamental importance of the network in the future education provision for Geosciences in the UK was outlined.

The Earth and Space Science Technological Education Project (ESSTEP).

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In the earth and space sciences, access to and effective use of computer, information, and remote sensing technologies are critical for students considering technical careers in environmental, natural hazards, land-use planning, and resource development fields. Currently, most secondary and undergraduate students do not have adequate exposure to or experience with these technologies. A decade ago, this problem could be attributed to inadequate equipment, facilities, and faculty professional development. Today, student access to good equipment and facilities has increased significantly, but faculty professional development remains a serious barrier to student understanding and use of these technologies. To increase the number of classrooms in which students have access to and the ability to use technological tools to investigate and solve real problems the Geological Society of America, Cypress Community College, and the Space Science Institute have created the Earth and Space Science Technological Education Project (ESSTEP).

ESSTEP is a faculty professional development project funded in part by a grant from the National Science Foundation. The primary goal of ESSTEP is to assist faculty in grades 8-14 with the effective integration of relevant educational technologies into their earth and space science curricula. ESSTEP brings together faculty from two- and four-year undergraduate institutions and secondary schools, with professional societies, businesses, and government agencies in a partnership that provides faculty with: (1) hands-on experience in state-of-the-art data acquisition, manipulation, and presentation technologies for the earth and space sciences, (2) innovative strategies for using technology in classrooms and laboratories, (3) internship opportunities in earth and space science technology fields, and (4) improved access to a wide-variety of technology-based education resources. More specifically, ESSTEP is assisting faculty to explore ways that technologies such as the Internet, Geographical Information Systems, Global Positioning Systems, multimedia, image processing, virtual reality, and three-dimensional modeling can be used to enhance student learning, promote science and technology careers, and catalyze the development of new courses and materials. Through earth and space science technology training institutes and a World Wide Web site, ESSTEP will directly serve 120 faculty during the next four years. These faculty will in turn provide inservice opportunities for an additional 1200 to 1500 faculty.

A Degree in Geochemistry: An Innovation for the Training of Professionals in the Area of Earth Science at the Universidad Central de Venezuela.

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Venezuelan economy is based on oil industry and mining and those areas demand a great number of professionals related to Earth Sciences. These professionals' working areas are interdisciplinary now more than ever; thus the help of various disciplines is needed to solve problems and to produce efficient answers. On the other hand, intensive exploitation of soil and undersoil resources and also the processing of raw materials creates high risk situations related to environmental pollution that should be minimized or solved by professionals who have an interdisciplinary and systematic view and are trained for sustainable development. At the Universidad Central de Venezuela, the Faculty of Science and the Faculty of Engineering (Geology) in a collaborative effort have been offering a geochemistry optional degree within the Chemistry School by the end of the career. This option allows students to acquire scientific knowledge related to geological materials, their composition and generating processes. Besides, this knowledge has a very high priority for economic development. This option deals also with situations related to agricultural activities, urbanization, use of water basins and other similar ones. The option has been very successful because during the period 1974–1992, 251 students have taken it and 145 have done their special research thesis on a geochemistry theme.

The need for geochemistry professionals has been established based on demands from employers. For that reason a university degree in Geochemistry has been offered since September 1996 at the UCV. The career has the following features:

1) Courses will make emphasis on basic knowledge of geology, chemistry and geochemistry with the assistance from Math and Physics. It is understood that this will provide a basic training, solid and at the same time flexible, trying to avoid less relevant, repetitive or highly specialized knowledge.
2) The more applied subjects will be offered by the end of the career. In this way a student can be employed as a geologist, chemist or geochemist assistant after she/he has accomplished the sixth semester. This will offer an intermediate degree within the career framework.
3) The scientific and technical knowledge will go along with general knowledge of oral and writing skills, English, computer technology associated to geology, economy and social subjects which will provide students with the necessary skills to fulfill their jobs with a social consciousness approach.
4) The special research thesis will be developed with two semesters of seminars by the end of the career. Students will be trained on information sources, and how to design, develop, present and discuss a geochemistry research project. It will be done this way in order to avoid one of the strongest reasons for a long study time (more than 10 semesters) at the university.
5) As a complement, graduated students could take a geochemistry postgraduate course at the ICT (Earth Science Institute) which is the oldest postgraduate course in the country and the first in Latin America.

Scientists, Educators, Students, NASA and Other Agencies Working Together to Develop Educational Products: What an Excellent Idea!

Carla Evans, Blanche Meeson and Becky Farr, NASA GSFC Distributed Active Archive Center, NASA Goddard Space Flight Center, Code 902, Greenbelt, MD 20771, USA.

How do you start? The Goddard DAAC is one of eight data centers for the NASA Mission to Planet Earth (MTPE) program that stores and distributes data formerly just to the Earth Observing System (EOS) researchers. Recently we have expanded our customer base from 114 science users in December of 1994 to 29,291 by June 1996. This was accomplished by expanding our product line to address the needs of high school, undergraduate and graduate education while creating new products for our scientific users. The amount of data files distributed increased from 1,102 for 1994 to over 60 million in 1995. We started by implementing the following ideas on how to share our data with other scientists, educators, and students:

- advertise
- understand needs, constraints & behaviors of our potential new customers
- actively solicit input on uses, needs, & value
- work with educators through summer internships
- attend our customer's workshops (education, science, & application)
- contribute data and information to workshops for teachers
- work with students (high school and college)
- work with educators to develop curriculum for our data
- involve educators in our educational product design & development
- have educators test and evaluate our products
- develop and collect metrics to chart the effectiveness of our products
- form partnerships with scientists, other agencies, educators, and students
- get involved with reform for Earth science education
- start a volunteer program

Recently NASA has realized that the public, educators and some Earth scientists know very little about efforts to study our own planet. NASA is well known for space exploration but not for the MTPE program. Scientists are usually busy writing proposals and finishing up research on one project while starting the next. They realize the need to do outreach but need help to be able to provide information that can be understood by the non-scientific community.

Our approach to developing educational products containing MTPE data includes enabling scientists to contribute existing information and graphics for use in the classroom, working with educators to help design, review, and evaluate the products, and forming partnerships with other organizations. This reduces costs, maximizes resources, enhances productivity, improves product quality, and enables innovative products and product uses.

SOME OF THE EDUCATIONAL PRODUCTS COMPLETED:

Goddard DAAC Data Starter Kits, Image Browser, Oceanography from the Space Shuttle

PRODUCTS IN PROGRESS/EXPECTED COMPLETION:

Goddard DAAC Earth Science Educational Series

TOMS data—Global Stratospheric Ozone/August 1997

AVHRR NDVI data—Global Land Cover/December 1997

CZCS data—Ocean Plant Concentration/March 1998

Geomorphology from Space/Summer 1997

Exploring U.S. National Parks from Space/Proposed project

TEACHER TRAINING WORKSHOPS AND CURRICULUM DEVELOPMENT CONTRIBUTED TO:

Maury Project (K–12), Discover Earth (K–12), Earth System Science Education (college)

INTERNSHIP PROGRAMS FOR EDUCATORS, TEACHERS IN TRAINING AND COLLEGE STUDENTS:

MSGC	Maryland Space Grant Internship for Teachers, 1995, 1996
MCTP	Maryland Collaborative for Teacher Preparation, 1995, 1996
NASA	GSFC Teacher Intern Program, 1996
NASA	Space Grant Academy Program, 1996
FRSO	Fellowship in Remote Sensing of the Oceans, 1996

ADDITIONAL PARTNERSHIPS:

JPL Data Distribution Lab

Scientists at NASA and Goddard Space Flight Center

U.S. National Park Service

Researchers at Universities

Visit our Web site to find out more about our data and products! *http://daac.gsfc.nasa.gov/*

Geoscience Education in Higher Technical Institutes: Indian Perspective.

D.K. Paul, Indian School of Mines, Dhanbad, INDIA.

Traditionally Geoscience has been concerned with the accessible components of the solid earth and more specifically with the exploitation of the terrestrial resources. More emphasis is now on the processes that operate and affect life on the planet. It has become imperative that the earth's processes are understood globally but applied locally.

Geoscience application has expanded beyond the mineral industry. Earth Scientists must assume roles outside traditional fields. To be useful to society, Earth Scientists have to address the requirements of ever growing needs of humanity for food, energy, habitation, ensuring that the environment is not affected.

Recent devastating earthquakes, cyclones, floods causing heavy loss of life make it necessary to understand the reasons and seek the remedies for these terrestrial processes. Recent earthquakes in Latur, India have destroyed the notion that Precambrian Cratons are stable blocks unaffected by earthquakes. On the positive side, plate tectonics have opened up the possibility of generation and recycling of natural resources.

Despite the increasing role of the Earth Sciences, the direct involvement of Earth Scientists in society has decreased, resulting in the loss of employment opportunities.

Earth policy planners and educators therefore have to play a positive role to chalk out earth science education for the Twenty first century. Those pursuing a vocation involving earth resources (e.g. mining engineers, petroleum technologists, metallurgists, civil engineers, etc.) have to be taught the basic principles with emphasis on the sociological and economic aspects. The basic sciences have to be included in the curriculum for the geoscientists focussing on the upper layers of the Earth which sustain life and environment. But research in the traditional fields must continue for the growth and indeed for the science to survive.

Experiential Undergraduate Geoscience Education—An Integrated Approach by the University of Hawai'i Marine Option Program.

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The University of Hawai'i Marine Option Program (MOP) provides undergraduates with a spectrum of ocean-related experiential learning opportunities throughout the ten-campus, statewide system. At one level, awareness of the marine environment is provided through recreational activities such as sailing and kayaking; short non-credit workshops may introduce students to coral reef species identification or fish printing; much more substantial workshops are offered for academic credit in the areas of reef surveying techniques and maritime archaeology. The program is open to students in any field of study who have an interest in the ocean and the initiative to complement their degree requirements with an experiential education package. Students may earn a certificate, analogous to a minor, by completing a core of 9–12 credits of coursework plus a research or internship project. Such projects are designed and conducted with the supervision of a mentor who may be a faculty member, a staff member in a government agency or a non-governmental organization, or who may be in industry. Geoscience projects have included beach dynamics, water quality, oceanographic cruises, nearshore bathymetry, coastal structure inventories, remote sensing, SEM analyses of sediments, historical studies of tsunami marigrams, marine education, software design, and geoarchaeology of traditional Hawai'ian fishponds. In addition to mastering the subject content of the project, students acquire valuable transferable skills (*e.g.* technical writing, time management, communication, application of scientific methods, teamwork, etc.) which better prepare them for employment or advanced study. Overall, MOP's educational design provides an alternative learning framework within the university setting which is often more productive for non-traditional learners and benefits the didactic learner by testing and reinforcing classroom concepts.

Session Summary

prepared by William Hoyt, Theme Session Coordinator. Discussion leaders for the theme session were Hoyt, Ed Geary and Beverly Lynds.

William Hoyt

Discussions following this Theme session focused often on the mechanisms used by successful programs to overcome the barriers that have faced us all. To assist others it was suggested that we needed to identify the barriers to successful reform projects. A long list of those barriers would include all of the subsystems of education that we work in—universities, departments within universities, teaching faculty at the secondary level, middle school level, elementary level. How do all those barriers between those groups and amongst those groups become broken down? One of the questions that they wanted to be sure we considered was, what incentives are there for someone to try to go "beyond the box" (attempt to implement new ideas)? What incentives are there for a teacher to reach out to other teachers? For a teacher to reach out to a government scientist? A government scientist to reach out to a teacher? And within the university promotion and tenure system, what incentives are there to help get away from our little feifdoms in the ivory tower?

The second break out group was very interested in pursuing the question of how to undertake effective Earth Systems Science teaching, to investigate the mechanisms of integration that have been successful—similar to what the first break out group wanted to investigate—but the big challenge they left for us to ponder was how to identify the common processes that can lead to solutions, not just in the classroom, but in global problems. What processes, what habits of mind, what attitudinal biases do we need to bring to actually approach solutions to problems? Another comment that the second break out group had was that "guided discovery" or "directed inquiry" methods in teaching were very effective, BUT we need to have motivated students and teachers. If we develop a most incredible description of what is a great program and try to implement Earth Systems, the students may not be ready. Openness to innovation is a critical element.

The third break out group focused on change in training university teachers—this may be threatening to some of us. In particular, they sought ways in which various countries and universities learned to value *teaching*, not just research. Higher education institutions often use models of large universities, and the research model is what is often exclusively used in decisions to hire and promote professors, not their ability in teaching. Comments from around the world confirmed this. A program has been developed in Great Britain where university lecturers and others in the university system can acquire a formal certificate, and in fact the government is encouraging/*requiring* that each college instructor and the professor will be able to obtain a certificate, credentials that are based on an understanding of effective teaching strategies. On the other hand, there are some concerns that Earth Science is being removed in the lower grades and in the universities in settings overseas. New Zealand echoed those comments both in terms of an optional teaching certificate for teachers to acquire—but it will be in the highly competitive market of teaching at Universities, it will be a tool, university-recognized in New Zealand anyway, as a benefit to have on your resume if you wish to teach in universities. For the examples from the U.S. we had comments from Pennsylvania State University, which has 17 separate geographic campuses that make up the Pennsylvania State system. For the first two years students go primarily to one of these smaller campuses, and for the last two years (the junior and senior years) they often go to the University Park campus to solidify the work in their major. At both campuses there is a strong emphasis on teaching excellence.

There are still questions that remain about how the characteristics of teaching excellence are advertised in job descriptions for new professors. All universities have concerns about that. Similar comments from Nebraska and Colorado and many other states that are dealing with concerns about licensing teachers at k–12. The U.S. rarely says a word about licensing teaching excellence or encouraging teaching excellence in colleges.

Finally, the discussants admonished us to analyze critically the areas in which the profession is growing, in acquiring students for study in selective programs at the college level. Every student that goes to college has a choice about a major. Students are voting somewhat "with their feet," especially in programs that are not looking ahead to the kinds of present and future careers which for students with geoscience training. No one can be sure about what that is, but we all agreed that if we don't think about those issues and have some serious intellectual discourse amongst institutions thinking about that issue, we may have more extinctions in individuals and in departments.

Session IB: College and University Curricula

Donald R. Johnson and Geoff Taylor, Moderators

The college (post-secondary) curriculum is critical academically for its modeling of interdisciplinary, systems-level thinking, and for development of understanding of the Earth system by non-majors. For the geoscience profession it is critical for retaining under-represented groups in science courses and careers, and for supplying geoscience professionals with skills for dealing with 21st Century science needs, technological tools and social responsibilities. The papers in this session represented the innovations being made by college educators on four continents. They included curriculum modifications specifically designed to serve non-majors, introducing them to an Earth systems science approach and applying their current knowledge into larger Earth frameworks. University faculties collaborate across continents and regions to produce course modules, entire courses, faculty development, and models of faculty-student interactions to facilitate learning. Special attention to field needs was a focus of several papers in the session, including summer sessions for high school students, attention to gender issues, and integration of subject areas in the field.

Discovery at Ricks College.

Steven C. Hansen, Geology Department, Ricks College, Rexburg, ID 83460-0510 USA.

Ricks College, a private two-year college with 8000 students, has had a multi discipline outdoor program for Biology, Geology, Health and Fitness for many years. Currently the program runs for five weeks with thirty students in each section. Regular college credit is given for the individual classes that are taken.

The concept of the program is to get the student out of the traditional classroom and give them a hands on experience with the subject material. The location of the college provides access to many different environments where science can be observed and experienced in a natural setting.

No texts are required in the classes. Reference texts, reports, and articles of interest, are usually available for the students. Lectures, demonstrations, and projects are based on the particular site the group happens to visit. Student reports and project reports are presented to the group. They are based on student observation, reference material, research, and aid given by the teacher. Group learning is encouraged and group projects can be carried out. A goal is to raise the group to a higher level of comprehension than is commonly obtained by individual study. An unspoken goal is for the more rapid learners to help those that may struggle with the scientific concepts. Some camp duties are required but the first priority for students is their natural world first hand.

Tests are oral based on discussions, lectures, or hand samples of rocks, plants, or animals that may be used to illustrate the goal the teacher has for the students. The power of this program is taking the student directly to the object or exposure and having a hands on experience with them about the material being studied.

Classes usually meet for an hour but if longer activities are planned the other classes can be adjusted to meet a specific need. In the evening the professors meet and work out the best time for their activity the next day. A list of the classes is usually written on a piece of paper and posted in the eating area so the students know the schedule for the next day.

A new section of this program was planned for summer 1997, featuring Geology, Biology, and Elementary Education classes. The lead department and major source of students is Elementary Education.

The Integrated General Education Science Curriculum.

Patricia Deen and Al Trujillo, Earth Science Department, Palomar College, 1140 West Mission Road, San Marcos, CA 92069 USA.

The Integrated General Education Science Curriculum (IGESC) Project provides a model for an interdisciplinary learning community within the sciences division at Palomar College. This two-year pilot project, established in the Fall of 1996, is partially funded through a grant from the National Science Foundation. Two lead teachers and seven faculty associates have begun to design an integrative curriculum targeting designated sections of general education science courses in biology, chemistry, physics, astronomy, geography, geology and oceanography. Implementation of the new curriculum strategies began in Spring 1997, and will continue through the Spring 1998 semester.

A newly-established computer lab provides hands-on experiences with state-of-the-art interactive technologies. Assignments incorporate use of the Internet, geographical databases, CD-ROMs, and virtual reality to enhance problem-solving, creative thinking, analytical, and communication skills. Promotion of science and technology careers is also addressed by student interaction with the professional scientific community via E-mail and through special guest lectures. Within the targeted sections, course assignments and collaborative research projects focus on the central theme of oceanography. Specific examples of the integration of oceanography themes include:

- analysis of sea water chemistry including solutions, precipitation, and pH.
- exploration of a virtual field trip site where students analyze historical and present beach profiling data to draw conclusions regarding beach processes.
- analysis of past El Nino events and use of real-time sea-surface and atmospheric data to predict future events.
- manipulation of a database with analysis of the biological response to the Exxon Valdez oil spill.
- interpretation and manipulation of tidal data to investigate tide-generating forces on Earth and other planetary/stellar systems.

An integral part of the project is the faculty enhancement component. Faculty involved in the project receive interactive technology training, participate in professional workshops, and meet with scientists in industry to develop technology-based resources and curriculum integration strategies. A Teacher's Resource Guide will be developed and another generation of faculty participants will be trained. The overall goals for the project are increased retention rate, increased persistence rate, and an increased number of students declaring science as a major. An ongoing evaluation process seeks to validate these goals. An Internet web site has been established for student use as well as for dissemination of information regarding the progress of this project. This web site may be accessed through the Palomar College home page at: *http://www.palomar.edu/*. Partial support for this work was provided by the National Science Foundation's Division of Undergraduate Education through grant #DUE-9651115.

The Cooperative University-Based Earth System Science Education Program.

Donald R. Johnson, Martin Ruzek and Michael Kalb, Universities Space Research Association, 8426 Polifka Road, Whitelaw, WI 54247 USA.

The Cooperative Universities-based Program for Earth System Science Education (ESSE) is an ongoing NASA-funded undergraduate interdisciplinary education effort led by the Universities Space Research Association (USRA). For the past five years ESSE has been facilitating grassroots cooperative efforts among scientists and departments within universities, among universities and between university and government science communities in areas relevant to earth system science and global change education. The overarching objective of ESSE is to accelerate development of an academic base for earth system and global change science within colleges and universities. The ESSE Program currently involves 44 institutions in the development of undergraduate survey and senior level earth systems science courses and teaching materials. ESSE partnerships with other education organizations extend earth system concepts to middle and high schools, schools of education and the Internet community at large.

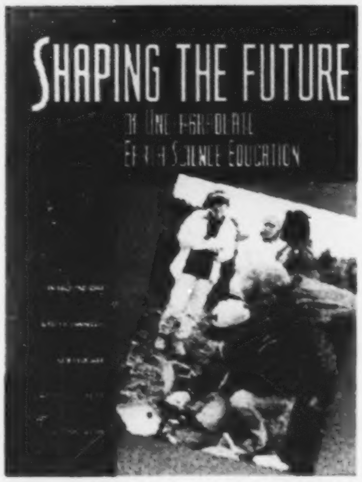
Many of the ESSE program participants are developing electronic-based teaching resources for use in their requisite survey or senior level Earth System Science classes. Some of these resources are organized as laboratory or classroom exercises, leading the student through text, data and graphics designed to describe and help understand a particular topic such as El Niño, ozone chemistry, population dynamics, etc. Others are software models of earth subsystems, such as the carbon cycle, using software such as STELLA. Recognizing that these modules are valuable hands-on active learning resources when documented properly and placed in a common repository, the ESSE server *(http://www.usra.edu/esse)* now functions to collect such resources to be shared by Earth System Science educators on the Internet.

At the most recent program workshop in August, 1996, ESSE participants initiated a formal effort to develop interdisciplinary earth system science educational modules containing materials and resources for application by all ESSE participants in their own courses. During the 1996/97 academic year, fourteen teams of 3–5 ESSE faculty and teaching assistants developed flexible educational materials for use in earth systems and global change courses suitable for electronic delivery. Module topics include: Observing Systems and Remote Sensing; The Biosphere; Atmospheric Ozone; Economics, Sustainability and Natural Resources; The Antarctic; Earth Energy Balance; El Niño—Southern Oscillation; Hydrological Cycle; Earth System History; Biogeochemical Cycles; Human Population—Environment Interactions; Health and Climate Change; Soil Processes, Land Use, Land Cover Change; and System Concepts and the Earth System. The primary intended users of the ESSE modules are university and college faculty developing earth system science and global change courses. The example offered by the ESSE participants is expected to stimulate contributions to modules from both within and outside of the Program with the ESSE server providing a flexible organized repository through which contributions will gain visibility and use among faculty nationwide.

Spheres of Influence: Shaping the Future of Undergraduate Earth Systems Science Education.

M. Frank Watt Ireton, Education Programs, American Geophysical Union, 2000 Florida Avenue NW, Washington, DC 20009 USA.

American Geophysical Union's Education and Research Directorate conducted a workshop in November 1996 entitled: Spheres of Influence: Shaping the Future of Earth Systems Sciences Education. This workshop was convened by the American Geophysical Union, with funding from the National Science Foundation (NSF) divisions of Undergraduate Education, Earth Sciences, Ocean Sciences, Atmospheric Sciences, and Office of Polar Programs, and in cooperation with the Keck Geology Consortium. The workshop brought together a diverse group of 48 faculty members, department chairs, deans, government representatives, and NSF observers. Participants for the workshop were drawn from research institutions and universities, colleges, community colleges, and liberal arts schools thus representing the breadth of disciplines in the Earth and space sciences.



Invited participants were assigned to seven working panels of six to eight colleagues each to consider specific aspects of undergraduate Earth science education. Three panels addressed why, how, and what to teach in an Earth systems classroom. Other panels discussed diversity issues, integrating research and education, and lifelong learning. One panel whose members consisted of deans or chairs discussed changing the culture of undergraduate geoscience education. Prior to the workshop participants received background information and several documents including a draft version of the *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1996) and the report from the Chapman Research Conference titled *Scrutiny of Undergraduate Geoscience Education: Is the Viability of the Geosciences in Jeopardy?* (AGU, 1994). List servers were set up for each panel to begin dialogues discussing their panel's topic before attending the meeting.

At the workshop participants then met as panels to discuss their topic in more depth and to begin to formulate their responses. A public comment period was open from December 15, 1996 and drafts of the panelist's responses were made available on the AGU website for comment by interested parties until January 15, 1997. The outcome of the workshop was a set of recommendations comprising a plan of action for the Earth sciences community to develop a coherent educational mission using Earth systems science as the focus. The final report, *Shaping the Future of Undergraduate Earth Science Education: Innovation and Change Using an Earth System Approach* (AGU, 1997), was released at an AGU Union session on education at the 1997 Spring AGU meeting. Additional sessions on the Spheres workshop, the report, and implementation of recommendations will be held at AGU and other society meetings.

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Research-Based Learning of Global Environmental Change Issues: Case Studies from Siberia and South Carolina.

Douglas Williams and Stefka Nikolova, Department of Geological and Marine Sciences, University of South Carolina, Columbia, SC 29208 USA.

"Research-based learning" is an innovative approach for undergraduate learning which is based on the organized use of interdisciplinary, thematic research, and related creative activities, as a vehicle for enhanced learning of complex scientific processes. Using a variety of research experiences from Siberia to South Carolina, this interactive poster session illustrated how research with an Earth System Science theme can function as a true learning tool for undergraduates. It showed what the students are capable of learning from this approach, what underlying principles and assessment strategies are useful, and how this approach can be used in other disciplines. We discussed some of the personal, professional and institutional challenges that must be faced in adopting these approaches at a research-teaching university.

Research-based learning is defined as the programmatic merger of discovery and investigation with an established, successful curriculum (in this case the interdisciplinary Marine Science Program). A "research-based learning track" (RBLT) is a means of implementing the researchbased learning approach. A RBLT functions by collaborative student/faculty teams working together, exploring together and learning together as they investigate important scientific problems. Ideally, the student-faculty team collaboration would extend over the length of the students' academic career and evolve into a partnership. A number of these partnerships working together would form a "community of learners," the model chosen by Project Kaleidoscope as ideal for "learning science" (PKal, 1991, v. 1, p. 42, Washington, DC).

The RBLT couples out-of-class research experiences, in this case dealing with the carbon cycle of Lake Baikal in Siberia and in the Pee Dee Watershed of South Carolina, with the established Marine Science Curriculum through a series of "critical connection courses." "Critical connection courses" are informal but rigorous, high quality special courses which reinforce and expand upon the principles and knowledge provided in our classrooms and laboratory sessions. This powerful combination represents a new, robust integration of research and learning.

The results to date are: a) an integrated, holistic approach to learning, b) new opportunities for students to gain critical hands-on experience using the latest technological tools and approaches, and c) practical experience learning professional and social skills in real professional situations.

Additionally students who have participated in our program have acquired and/or developed professional skills needed to excel in the evolving work place including:

- critical and independent thinking
- problem solving
- decision making
- teamwork
- planning, organizing
- communicating, writing
- flexibility and adaptability
- leadership
- respect towards individuals of diverse talents, backgrounds and learning styles.

The concepts, protocols and approaches of Earth System Science are ideally suited for the use of research-based learning. Research-based learning makes the excitement of research (discovery) an integral part of the student's academic life, not a "frill or exception to the rule."

Female-Friendly Geoscience: Eight Techniques for Reaching the Majority.

Darlene Richardson and Connie Sutton, Geoscience Department, Indiana University of Pennsylvania, 1224 School Street, Indiana, PA 15701 USA.

One of the ways to alleviate the under representation of women in science, engineering, and mathematics is to change how and what we teach in science classrooms. Women's Studies scholars have explored ways in which science as it is currently taught and practiced may reflect a masculine approach to the world which tends to exclude women. *Teaching the Majority*, 1996, edited by Sue Rosser, looks at how transformed college science courses may attract and retain women in science, mathematics, and engineering. The book includes descriptions of changed course content, syllabi, teaching techniques, laboratory exercises, and problem sets developed to appeal to women students (while also retaining an appeal to all other students).

One of the chapters in the book was written by Richardson, Sutton, and Cercone of the IUP Geoscience Department. They developed eight techniques which have worked for the IUP Geoscience Department to create a more "friendly" learning environment. The following methods engage students' interest and encourage their participation in lecture, laboratory and field exercises. Some methods are suitable for upper level classes while others can be used in large lecture classes. Not all will apply to every college environment, but putting any of them into practice will have the benefit of making geoscience friendly not only to women but also to non- traditional science students.

Four techniques relate to good teaching practices in general: 1) Demonstrate the relevance of classroom science to students' everyday lives; 2) Use a range of assessment methods to allow students to draw on their intellectual strengths; 3) Use non sexist language where possible—it doesn't hurt to refer to a tyrannosaur as "she"!; and 4) Encourage students to question assumptions and be comfortable with uncertainty. Other techniques are more geo-specific: 5) Separate non major students from majors in introductory labs, to reduce the need for teaching discipline specific classifications and specialized language to non majors; 6) Incorporate reading materials such as geological novels and non fiction in addition to textbooks; 7) Design field trips to emphasize the social context of geological processes; and 8) Do not stress physical accomplishments in the field or divide field or lab tasks by gender.

Staff Development in the Earth Sciences: A Discipline Versus Generic-Based Approach.

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The Higher Education sector in the UK is well provided for in terms of generic staff development. Centralized development-organizations within individual institutions successfully provide services in teaching and learning to many general areas of academic practice. Departmental-based staff development can be a highly successful means of supporting staff in response to the changing educational environment and to the multiplicity of subject-specific assessments. However, the needs of all academic departments are not the same and the diversity of teaching and learning environments demands a more focused, subject-specific approach. The extensive range of learning environments within the Earth Sciences is not exceeded by any other discipline as it includes fieldwork, personal mapping projects, self-directed project work, seminars, workshops and debates, in addition to the more conventional lecture, practical and tutorial environments. The Earth Sciences, therefore, provide an ideal test-bed for a pilot scheme of discipline-based staff development and, to this end, a three year project has been established to promote and implement a series of workshop courses designed specifically for the requirements of the Earth Science community in the UK.

The optimization of the benefits to the Earth Science staff and ultimately their students, is achieved by concentrating on the current, pre-eminent concerns in Higher Education such as dealing with large numbers of students and utilizing technology to aid the teaching and learning process. All UK academic staff are encouraged to be actively involved in the project. At the initial stage a survey was conducted to provide all Earth Science staff and some students with the opportunity to express their views on the project and to contribute ideas and comments on the desired format and content of the workshops. Each workshop provides a forum for the transfer of teaching and learning practice at a national level and utilizes the experience and expertise of academic staff in conjunction with contributions from relevant employers and professional bodies such that the best practices in teaching and learning can be identified and disseminated. Identification of the best practices currently operating in Higher Education can be made by collating information provided in reports from the recent Teaching Quality Assessment. This information, together with manuals and other material arising from the workshops will be made freely available to the academic community via a World Wide Web site. The aims of the project are to establish an innovative mechanism for the transfer of teaching and learning practice by using the subject-specific context at a national level and to constitute a culture of self-sustaining discipline-based staff development in Earth Sciences. This presentation discussed these aims and outlined the progress of the project and the success of the workshops to date.

A Vision for Expanding the College of Science.

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To date the College of Science has operated within the Faculty of Science and served as a means of increasing access and success of academically disadvantaged students wishing to register at the University of the Witwatersrand, Johannesburg, South Africa. Since its inception in 1991, the College of Science has received in excess of a thousand applications annually, however, due to limited resources, is only able to accept 180 students into the first year (of two years) programme.

The original vision of the College of Science was to increase the pool of scientists represented by the historically disadvantaged constituencies. This was successfully achieved by providing an enrichment programme, comprising a fully integrated science curriculum, to students who would otherwise have been denied access to the university. Although this has been successfully achieved the limited student intake each year has frustrated both College staff and unsuccessful applicants. For this reason the College of Science is looking to expand its vision to reach more students and to increase its influence on the future of South African scientists.

The College of Science is currently investigating ways of upscaling its programme to a more "developmental" model by considering alternative approaches. The options investigated include "franchising" the College Programme to other academic institutions and developing "distance learning" packages from established College materials that could be marketed to the South African public as a whole.

Initial findings have resulted in the College of Science pursuing the "distance learning" model as a means of realizing its expanded vision. To successfully achieve this, College staff have been consulting with other agencies that have expertise in this field (the Open University, UNISA, South African Institute of Distance Education) and are currently upscaling materials into "distance learning" packages. We reported on developments within the College of Earth Sciences programme and suggested ways in which the South African Mining Industries can contribute to, and benefit from, "distance learning" in Earth Science.

Earth Sciences Articulation in the College/University System, Province of British Columbia, Canada.

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Webster's dictionary defines articulation as the 'act or manner of joining'. As used here, articulation refers most specifically to the meshing of content of course offerings from different institutions. In British Columbia, we have an organization that we believe may be unique in its function of addressing this and related educational concerns.

The BC Earth Sciences Articulation Committee is a government-sponsored organization which meets annually to bring together teachers of introductory geology from three universities and fifteen colleges from across the province. Its beginnings go back to about

1970, when a need arose to coordinate the teaching of introductory geology at the newly-created network of community colleges, with the existing geology program at the University of BC. From an informal start, the association has evolved into the present Committee, which is formalized under the umbrella of a Provincial Government agency (BC Council on Admissions and Transfers). The Earth Sciences is one of about 75 disciplines that have independent articulation committees within the province's post-secondary academic system. Government sponsorship ensures that all institutions actively support the articulation process.

The objectives of the Articulation Committee are to:

- examine and share curriculum content, resources, and teaching methodology;
- facilitate transferability of course credits, mostly from college to university;
  - provide opportunities for professional development, mainly in the form of field trips;
  - promote professional interaction, and provide support for members and programs;
  - present a forum for liaison with industry and government agencies;
- maintain a dialogue with representatives from the secondary-school system, and
- offer educational support for high school earth science and geology programs.

The annual meeting comprises a business session and a field excursion, and is hosted each year by a different institution. This provides an opportunity to visit a variety of geologic regions around the province. For example, the 1997 meeting included an extended visit to the Queen Charlotte Islands.

A particularly ambitious project for the Committee was the organization of an exceptional 5-day field course in May 1996, which examined the terrains of the southern Canadian Cordillera, from Calgary to Vancouver. Financial support for this was obtained from both industry (Canadian Society of Petroleum Geologists) and government (Canadian Geological Foundation).

We submit that Earth Science articulation in the college/university system in British Columbia has been remarkably beneficial, and could provide a model for other educators to consider.

The Use of Summer Schools as a Way of Promoting Earth Science.

Geoff Taylor and Malcolm Buck, Department of Applied Geology, University of New South Wales, Sydney, AUSTRALIA NSW 2052

Secondary School science enrollments in Australia over the past six years have dropped by an average of 16% in chemistry, 18% in physics, 19% in biology, and 53% in geology. Enrollments in the geoscience courses at most Australian universities have experienced a similar reduction. In an attempt to address a potential shortage of geologists in Australia the Department of Applied Geology, at UNSW, has launched a program of action to increase the profile of geoscience in secondary schools and the wider community. Our aim is to encourage students to embark on a university course, and ultimately a career, in the geosciences.

In 1996 and 1997 our main strategy has been to present summer schools to Year 11 and 12 students held in the January summer vacations. Referred to as Geoscience and Mining Adventure Schools, these summer schools involved around 25 students selected for their aptitude in science and were comprised of 3 days of "hands on" laboratory experimentation at UNSW and 4 days of field study. In 1997 the field study included a shipboard study of sedimentation and environmental impacts on a local urbanized harbor, the field geology of the Sydney Basin and adjacent regions, and visits to local exploration and mining camps.

Discussions with participants during the Adventure School uncovered a startling ignorance of earth science systems in Australian secondary school students. However, analysis of post summer school participant questionnaires showed a high level of appreciation of the summer school and a significant increase in interest from participants in pursuing a career in earth science. All topics presented during the summer school were well received but those involving field work were enjoyed the most. Although all students possessed an idealistic environmental perspective, they were equally enthused by the underground mine experience, as they were by the study of sediments in a spectacularly beautiful coastal environment.

Earth science teaching staff at UNSW believe that a prevailing low level of interest in the pursuit of earth science related careers is a function of a widely held community attitude that there are few jobs and that rewards are low. In Australia this is a fallacy but it is proving difficult to dispel. Most students learnt about the Adventure School through their Science Department Coordinator, proving that other advertising methods were of little value. Limited availability of staff does not allow us to run the Adventure School more frequently than once a year. However we are currently attempting to achieve a "multiplier" effect by reporting the activities of the School in the relevant teachers' newsletters and journals. We believe that for earth science to prosper, many initiatives of this kind have to be taken, and that a long term policy of cooperative interaction between the mining industries, tertiary earth science educators and the secondary school system has to be followed. In 1997 we raised industry sponsorship of $A15,000 for the summer school, indicating a high level of support for our initiatives.

Geoscience Education in Zambia: A Way Forward.

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Mining in Zambia has been practiced for centuries, but it is only in the last 70 years that Zambia has risen to become one of the world's leading copper producers that resulted from the exploitation of the Zambian Copperbelt orebodies. However, geoscience education has been in existence for only 22 years at higher education level. The educational system in Zambia consists of Primary Education (Grades 1–7), Secondary Education (Grades 8–12) and Tertiary Education (Colleges and Universities). No geology curriculum is taught at primary or secondary education. Out of 25 colleges in the country, only one offered some geology courses to mining engineering technician and technologists, but this college has been elevated to university status resulting in two universities in the country, namely the University of Zambia and the Copperbelt University. The Copperbelt University specializes in programs that are not offered at the University of Zambia and carries on with the technician and technologist programs. The only geology program in the country is offered in the Department of Geology housed in the School of Mines with two other departments, Mining Engineering, and Metallurgy and Mineral Processing. The University of Zambia was built between 1965 and 1966 and the School of Mines was added in 1974 mainly to produce graduates in the three fields for the Copper Mining Industry, under one conglomerate known as the Zambia Consolidated Copper Mines (ZCCM). Students are enrolled in the School in the second year after spending a year in the School of Natural Sciences studying chemistry, biology, mathematics and physics. The school admits an average of 50 students per year. Geology enrollments vary from one to a maximum of twelve students whereas enrollments in the other two disciplines are over fifteen students each. So far only two female students are studying in the School of Mines, both of them in geology. The department will graduate its first female student this year since its inception in 1974.

ZCCM became the main employer for graduating students in the School of Mines and provided scholarship for their study. However, geology graduates also find work in the Government institutions such as the Geological Survey Department, the Department of Water Affairs, the universities, and the National Council for Scientific Research. Good conditions of service including salary are offered by ZCCM in comparison to the government. Once employed at an operating mine of ZCCM, a graduate geologist could rise to a position of a Chief Geologist whereas their counterparts (Mining Engineer and Metallurgists) would rise to the General Manager.

Results from a questionnaire and interviews suggest that a lack of high top positions for geologists in ZCCM and an unawareness of geology as a career are the main reasons for having low enrollments in geology. In Zambia, prospective students come to hear about geology when they enter the University of Zambia's School of Natural Sciences. Secondary School students look at geologists as people who break stones, whose future lies in ZCCM, and who cannot be equated in any way to Zambian household careers of an engineer, accountant and a medical doctor. Unfortunately, this view is held by some of our politicians and many parents, and these influence careers to be chosen by their children. The "Geoscience in School" project is a program started in 1994/95 with its first inaugural seminar at Maamba Secondary School in Southern Province. The aim of the project is to make Secondary School students aware of geoscience, what it can offer and that it embraces many disciplines including engineering. The students are encouraged to form geoscience clubs where they can come up with projects and make field trips to geological sites.

The main goal of project is to influence inclusion of geology in the curricula of Grades 8–12 and to send a message to the students that geology embraces other fields and in fact geologists are better placed people in the understanding of our environment. Renewed exploration activities in Zambia since 1991, the use of job opportunities in new mine ventures by politicians in their campaign strategies in the media and the readily available employment for geology graduates assist in attracting a number of students to our seminars in the Secondary schools. These exploration activities, the world wide campaign for a clean and better environment, and indeed our own initiatives such as this one, are opening new grounds for Zambian geologists. These initiatives will result in educating future policy makers who in turn may influence job creation and opportunities in the government ministries of Environment (e.g. at the Environmental Council), Energy, Science and Technology. These new job opportunities will result in more geoscience enrollments and hence, enhance the faculty and public literacy in the earth sciences.

Improving Science Literacy in General Education: An Interdisciplinary Course Sequence in Earth System Science.

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Our goal is to improve the scientific literacy of Hartwick College students, and in so doing, develop a successful model for reform that might be adapted to the needs of other institutions. We have revised our general education curriculum so that students gain a much fuller appreciation of what science is, how science is done, why science is important, and most significantly, a solid understanding of some of the important issues in modern science. We hope to engender in students the confidence and the ability to make informed decisions about science and technology issues. We feel that the most significant barrier to increased scientific understanding is the lack of connection between the science courses offered to non-science majors. These courses are designed with the assumption that students have no prior knowledge of the subject matter and have limited mathematical skills. Thus at Hartwick, where students must complete three math & science courses to graduate, each faculty member starts from scratch and cannot build on the efforts of our colleagues who may have taught these students in previous semesters. Additionally, as math is currently removed from coursework, students see math as a completely separate enterprise, rather than as an integral part of science. This approach effectively cheats students of the thorough science education that they deserve. Furthermore, by requiring courses to be distributed across different departments and allowing students to take the courses at any time, we make it extremely difficult for students to see the connections between the various scientific disciplines. We force science to appear fragmented rather than coherent.

We have developed a year-long series of three sequenced, thematic, interdisciplinary courses in Earth Systems Science that satisfies Hartwick's general education requirement. The program is staffed by members of the departments of mathematics, biology, chemistry, and geological and environmental sciences. We examine global environmental concerns from the point of view of Earth Systems Science. Each term's class has a focus area, the hydrosphere (Fall), atmosphere (Winter) and lithosphere (Spring). Mathematical concepts are incorporated across the three semesters, as are topics highlighting the interrelations of these Earth systems with the biosphere, focusing especially on human societal concerns. Through a combination of activities, including "hands-on" experience with scientific equipment and data collection, with computer simulations and modeling, with field excursions, but most importantly through exploring and constructing their own understanding, students gain not only a better understanding of the Earth system, but also a better understanding of the importance of science in their lives and in their futures.

Session Summary: College and University Curricula.

These discussions were summarized by Vic Mayer from notes provided by each of the moderators: Mayer, Goeff Taylor and Donald Johnson.

Our discussions ranged widely in order to identify issues in Earth science education that seemed to be international in scope. They included the following:

There seems to be a lack of awareness among the public at large of science in general and Earth science specifically. The general consensus was that there was

little attention paid to the earth sciences among leaders in education. It seems not to be valued as an integral part of a broad program in science literacy. In most countries, what little is taught in the Earth sciences comes through geography programs rather then the sciences. There seem to be only a few exceptions to this, including some of the Asian countries and South American countries in addition to the USA, where the Earth sciences are taught as a component of science programs in the pre-college curricula. At the university level, nonscience majors especially seem to fear the sciences, electing not to take them if possible, or if necessary only a very limited introduction to the sciences.

Many felt that to overcome this fear of science at the university level, small classes were necessary rather than the typical large lecture section. There seemed to be agreement that class sizes of 10–15 would be ideal. To achieve such a class size, however, would require extensive resources unless there were some very creative solutions. One that was suggested, and seems to be successful at Montana State University, is the use of peer mentoring. Students who have been successful in the beginning Earth science courses are brought back as undergraduate student assistants to mentor fellow undergraduates currently enrolled in the course. Another possible solution are forms of cooperative learning, now used successfully by middle school and secondary school teachers, as well as in some teacher summer institutes in the USA. Cooperative learning, combined with the use of computer technology and especially the Internet as a resource for student learning, can change the nature of learning at the university level.

Many were concerned about falling enrollments in Earth science at both the pre-college and the college level. Certain countries, such as South Africa, have eliminated Earth science from the national curriculum. In others, such as Japan, enrollment in earth science at the secondary level has fallen by some 50% as a result of changes in science requirements. This seems to be a general situation around the world where there is a reduction in Earth science enrollment at the pre-college level. With fewer students taking Earth science at the secondary level, fewer are encouraged as a result to enroll in Earth science courses at the university level.

Earth science is a "minority science." It is not seen as important by those in biology, chemistry and physics and therefore by curriculum leaders in pre-college education. It also does not have a strong political base within most universities and governments. Therefore it is given "short-shrift" when it comes to securing a place in the curriculum. It is also especially susceptible to cuts in funding and time. In some countries the Earth science education community itself is divided. In the USA for example, there are the geologists, meteorologists, astronomers, and oceanographers, each trying to maximize their hold on a very small part of the curriculum and instructional resources. Often they work at cross purposes. This reduces even further an already weak political position vis a vis the other sciences. Fortunately these groups were able to work together to secure a respectable place for Earth science content in the new national standards developed by the National Research Council.

One way to reverse the weakening political position within the sciences is for the Earth sciences to work together to develop integrated Earth science courses. This has been done at the university level at Hartwick College in Oneonta, New York. It is also happening in the Earth System Science Education programs that are now being offered in some 40 universities across the USA.

Other university level issues identified by the discussion group were those of gender bias in instruction and curriculum, and the inclusion of academically disadvantaged students in degree programs. Problems and solutions of both of these issues vary across countries and few solutions were offered.

Another discussion group for this session identified the lack of ability and enthusiasm displayed by elementary and secondary school teachers toward the earth sciences as a major problem, especially geology. This has the tendency to "turn off" students to these sciences and to impede their learning of important concepts and skills associated with the Earth sciences.

Universities and colleges must provide appropriate resources and training to equip elementary and secondary teachers to teach the geoscience parts of their general science programs. These should include the provision of field guides to local areas, rock and mineral specimens, and workshops in field skills and geological topics. Strategies must be developed to enlist more geology-trained teachers into the elementary and secondary schools.

There is a need to ensure that;

- within an environment of merging geoscience departments in universities and colleges and the emerging popularity of the environmental sciences, that geology plays an equal part with the other sciences. Anecdotal evidence suggests that there is a world wide trend for environmental science to be biology driven.
- there is a collaborative approach between community colleges and universities to enable students to progress without difficulty from one to another institution.
- college and university faculty and staff working on outreach activities receive appropriate recognition for this work. Teaching and learning should rate equally with research.

Session IC: K–12 Curricula

Masakazu Gotoh and Dan Jax, Moderators

In this group of posters were descriptions of K–12 programs that pull together large components of the school curriculum and typically require more than a week of instructional time. Some were units of instruction, and others articulated programs that span several years of the curriculum. Several presenters provided models of how science can be integrated with other curriculum areas (math, social studies, the arts) through studies of rivers, rainforests, and Earth representation through satellite images. Innovative methods used by some presenters may be useful in many K–12 situations, such as learning about Earth systems on a need-to-know basis for problem solving. Many of the posters dealt with field experiences to promote synthesis of information and establish cognitive frameworks for construction of knowledge. Students in these programs may emerge with the ability to think globally based on local experiences.

The Wailuku River: A Model for Earth Systems.

Raymond L. Tschillard and William H. Hoyt, University of Northern Colorado, Greeley, CO 80639 USA.

As a result of numerous national studies since the 1980s, science teachers have become acutely aware that traditional delivery of science content does not reach many students. Consequently, several curriculum change proposals have been brought forward.

The curriculum change process in the nation's schools looms as a formidable barrier to school restructuring. New strategies are needed to convince teachers that there are better ways to develop an integrated curriculum that is both exciting to students and academically rigorous. Considering the school curriculum as a study of the Earth and its systems does provide a new paradigm for a relevant, engaging, and rigorous approach for integrating the sciences with art, literature, social studies, language, and other disciplines. Using the nationally-tested philosophy of the Program for Leadership in Earth Systems Education (PLESE), the University of Northern Colorado Laboratory High School Science Department proposed to model the "systems thinking" approach with a science course called "Natural Science Field Study."

The idea was to study a local river, the Cache la Poudre, as a system, using an integrated, interdisciplinary approach. Instead of teaching biology, geology, chemistry, and physics separately, it was the intent of the new class to allow students to learn and understand science concepts by analyzing a river system out in the field. Back in the classroom, students correlate the data to see how science disciplines are related to each other, as well as to all other disciplines. The premise of this effort is that solving global problems requires understanding the entire set of interactions between the various systems involved. The systems approach is in direct conflict with the reductionist approach that instructs students in one narrowly-defined discipline at a time and discourages connections to other disciplines.

The purpose of this poster session was to model a river system, the Wailuku River, as a microcosm of global problems. By taking a concrete, local example of a study site, each participant can transport and apply the idea back in their communities.

The posters showed participants studying the Wailuku River at three different sites: 1) Mauna Kea Forest Reserve (bridge access from Observatory Road); 2) just east of Hilo Forest Reserve, and; 3) the river delta into Hilo Bay. At each location, the participants analyzed the chemistry of the water, collected and identified aquatic organisms, labeled, analyzed, and mapped the substrata of the river, and measured and calculated the physical characteristics of the river systems. Participants were asked to observe the aesthetics and stewardship of the river sites and to construct a transect map of the study location.

From Pebbles to Moon Rocks: K–8 Earth Science Curriculum.

Susan K. Jagoda, Lawrence Hall of Science, University of California, Berkeley, CA 94720-5220 USA.

When a geologist encounters a problem such as determining the origin of a rock, she first observes the rock's properties. She uses her communication skills to describe the rock. Through comparisons with other rocks, she organizes her observations and looks for relationships that will help her infer the rock's origin. She then applies her new knowledge as she continues her explorations of the earth's crust.

When a young child first encounters a rock, she follows the same path of discovery as the geologist. At this age (PreK–2), observations and comparisons of the rock's properties and words to describe the properties occupy the youngster's mind. Third and fourth grade students exercise their organizing skills as they seriate and group earth materials. Fifth and sixth grade students start to identify relationships between earth materials, such as the relationship between a stream's slope and the amount of erosion that occurs. By the time students reach grades seven and eight, they can use their prior knowledge to make inferences about the origin of the Moon after observing simulated moon rock samples.

The Full Option Science System (FOSS) program at the Lawrence Hall of Science at the University of California at Berkeley (UCB) has been in development since 1988 with funding from the National Science Foundation. FOSS bases its curriculum development process on research by Dr. Lawrence Lowery which focuses on the biological basis of thinking and learning. Science is a pattern-seeking enterprise—an expression of the human capacity to think. FOSS is designed to help students develop their pattern-seeking abilities and to capitalize on the scientific thinking processes—a set of thinking capabilities (observing, communicating, etc.) that appear at intervals that are spaced well enough apart to allow the current capability to become established. Research suggests that there are periods in human development in which certain processes have a higher payoff for learning. FOSS strives to design hands-on science activities that focus on these periods for each grade level.

There are presently six modules in the FOSS K–6 program that emphasize earth science concepts. The developers' task was to identify concepts and activities that would be appropriate for learners at the grade school level and that would allow them to build their knowledge of the Earth and its systems. For example, at Grades 1–2, the Pebbles, Sand and Silt module guides students into discoveries of rock properties, emphasizing their capabilities of observing, communicating, and comparing. They sort and seriate rocks by different properties, knock rocks together, get them wet, use them to construct bricks, and build their vocabulary for communicating their observations and comparisons.

This poster session exhibited samples of the FOSS K–6 Earth Science strand modules and displayed some of the current development at the middle school level. A goal of the session was to promote discussion about the appropriate concepts that students need to grapple with at grades K–6 that will help them continue constructing ideas and knowledge about the Earth and its systems.

"Environmental Solutions" An Integrated Study of Hydrology.

Brad Parkinson, Brent Blake, Nancy Winmill, and Jackie Johnson, Madison High School, 4293 S. 2000 W., Rexburg, ID 83440 USA.

Visualize dozens of students scattered along the banks of the Teton River and its tributaries located in southeastern Idaho. Many wear waders and are in the water taking a kick sample to gather macroinvertebrates, others are using sophisticated equipment to test the water for minerals and chemicals, and some are assessing the riparian habitat and doing a general stream assessment. Students are carefully recording data in their field journals. This is what you would see any day if you visited Madison High School's Environmental Solutions class in Rexburg, Idaho.

Environmental Solutions is a "school within a school" integrating English, chemistry, statistics, and environmental science to offer students an in-depth, hands-on study of the Teton River Watershed. The entire Teton drainage is directly or indirectly affected by the water quality of the river. The information gathered by the students will be used by local businesses and agencies to make determinations about future policies and procedures affecting the water quality. Students gain experience in real life problem solving, have the opportunity to work with professionals, and are exposed to a variety of career options. Students are also able to see how all subject areas are truly integrated and how information learned in school is applied to the real world.

The class is composed of 50–60 juniors and seniors for one 12-week trimester. Students are in the class four consecutive 70-minute periods of a five period day. Initially, students are professionally trained to work in teams. They also learn effective teamwork by observing the teaching team.

The science class is the basis for the entire project. Chemistry focuses on the chemical testing of the water and the training on advanced technology. Statistical mathematics is used to collect, graph, analyze, and interpret the findings. English instruction centers on the importance of accurate recording of data in a field journal, technical writing, and creative nature writing. Students are trained to use still and video cameras to document their activities. Each team produces a multi-media presentation at the end of the course. Technical writing becomes a major focus in the class as the students compile and analyze their findings which will become part of the worldwide web.

One of the most positive aspects of this class is that it is student-driven. Once students are trained to do the assessments, the teaching team merely oversees. Students truly become experts at assessing the water quality, and analyzing, organizing and presenting their findings. They become keenly aware of hydrology and the integral position it plays in all environmental issues. The class does much to promote responsible stewardship of all the earth's resources.

An Inquiry-Based Approach to Learning Earth System Science.

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NASA Classroom of the Future (COTF), Wheeling Jesuit University, 316 Washington Avenue, Wheeling, WV 26003 USA.

OBJECTIVES OR PURPOSES

In this study we examined variables involved in designing and implementing high school Earth System Science multimedia educational tools that effectively address the goals of the 1996 NRC National Science Education Standards. These guidelines reflect the goals and principles of curriculum reform efforts that seek to move classroom environments toward student-centered inquiry and authentic learning activities. This case study described the design, development, and one school year's classroom testing of the Exploring the Environment (ETE*) Project. By examining the selection of the scientific framework, nature of the problem being articulated and modeled for students, and design of learning activities, this case study suggested a process for generating curricula that foster scientific inquiry within a student-centered, technology-rich learning environment.

METHODS, TECHNIQUES OR MODES OF INQUIRY

The development team created environmental Earth science modules that use satellite imagery as a tool, problem-based learning as methodology, and the World Wide Web as a means of delivery. During the 1995–96 school year the ETE curriculum was evaluated in eight high schools across the country; over 300 students participated. Students were introduced to authentic environmental issues within the context of an ill-structured problem. Most problems dealt with human interaction and impact upon the environment, such as water quality, habitat destruction, or biodiversity. Available to students were a standard problem solving model, on-site resources, and recommendations for extended inquiry. Student-directed research generally lasted a minimum of five weeks but often extended throughout the semester. Working cooperatively, students engaged in problem-based activities requiring them to formulate problem statements, collect and analyze data, then prepare and present their findings, solutions, or recommendations.

EDUCATIONAL OR SCIENTIFIC IMPORTANCE OF THE STUDY

This project demonstrated that within a technology-rich environment using problem-based learning scenarios, students can be engaged, motivated, and deeply involved in learning both process as well as content. More important perhaps are questions concerning those classrooms in which students were not as engaged or interested in learning. This presentation addressed variables that may account for less-than-hoped-for results. Among initial indicators are: the relevance of the problem to the students; student age and ethnic background; social-economic-status; the teacher's skill in handing inquiry environments; regional differences; prior knowledge; and the students' experience in selfdirected learning environments. Design considerations, especially in the area of creating relevant, authentic contexts for learning, and implication for teacher workshops and support materials were addressed in this presentation.

The ETE project was developed at the NASA COTF. Funding for ETE was provided by the Information Infrastructure Technology and Application Program under cooperative agreement NCC5-107.

Geoscience Content as a Part of an Integrated Earth Systems Approach in Middle School.

Dan Jax, Bexley Middle School, 2356 Brentwood Rd., Bexley, OH 43209 USA.

The science curriculum at Bexley Middle School is based on an Earth Systems approach that has been developed over the last several years through projects at The Ohio State University and the University of Northern Colorado. Earth Systems is an integrated approach to the teaching and learning of science that uses Earth as the context. Earth is composed of the varied systems of air, water, land, life, and ice. These systems do not exist independently, but interact in a variety of ways. It is the interactions among these systems and the human impact on these interactions that we focus on in the science curriculum at Bexley Middle School.

Specific topics that include integrated science content are Ecosystems, Population Dynamics, Resources, Wetlands, and Change Through Time. These are topics that show up in many different biology, and maybe some earth science, curricula. By exploring how we study wetlands, the integrated nature of the curriculum may be revealed. We begin the school year by looking at humanconstructed drainage systems in our city. Students locate storm sewer openings in curbs and streets and use maps from the city to find out that storm water (and anything else dumped on the surface) ends up in the local stream. They are able to identify storm sewer drainage divides and basins. Students realize that their city is not isolated from the surrounding areas when they see how water moves into, through, and out of the area.

From this introduction, students study natural drainage systems using topographic maps and discover places where water does not drain well and produces wetlands. All students participate in a full day field trip to a local wetland (a Metro Park). On this day, students collect data about all of the following:

1. microscopic and macroscopic organisms in the water—identify and record what they are doing,
2. macroscopic organisms *on* the water (mainly birds)—identify and record what they are doing,
4. macroscopic organisms on land adjacent to the water in two different areas—identify and record what they are doing,
5. rocks found in the soil—describe and identify,
6. chemistry of the water and soils (from two different places),
7. temperatures of the soil, water and air (at three different levels)—includes continuous sampling of soil and air temperatures over a three hour time period using a calculator and CBL,
8. general description of the soils, and
9. obvious changes in the wetland in the recent past.

Extensive preparation and follow-up is done. Relationships among the data are discussed and explanations emerge. Finding rocks from Canada in the soil reveals the glacial origin of the wetland (a kame and kettle complex). The role the rocks play in determining the chemical parameters of the water the students measured is discerned. How the chemistry of the water and soil affect the organisms that live there is explored. The idea of microclimates and the factors that affect them comes from the soil descriptions and temperature data, particularly the time-series air temperatures. Students can explain why soil and groups of organisms can differ between two places that may only be 50 meters apart.

An important part of the follow-up for this trip is deciding what kind of impact humans have had on the wetland. A few things are obviously recent (tree lines from a field, old part of a roadway). The wetland is surrounded by farmland. Students use the chemical data (especially nitrate and phosphate levels) to try to evaluate the effect of chemical run-off. The area is also starting to be developed with single-family homes. After studying runoff in our city, students predict what future effects this development may have on the wetland.

The wealth of data lends itself to using a jigsaw approach in the classroom. Using the collected data and doing additional research, groups of students become experts on different aspects of the wetland. Each group presents their information in printed form along with a presentation. This is followed by a written report done by all students based upon the reports of all the groups. The relationships among the different parts of the wetland, including the interactions of the subsystems of air, land, water, life, and ice are described by the students. In this way, they develop a broad view of what a wetland is, how it is valuable to humans, and how humans can have an impact on it. Perhaps it is apparent that all five of the topics listed above as being integrated are a part of our study of wetlands. When you study Earth as a set of interacting systems, you are doing science in its most complete and understandable way.

When restructuring a science curriculum using an Earth systems approach, there is much more involved than integrating content and changing perspectives on that content. Group learning and alternative assessment provide students opportunities to share knowledge in a variety of contexts. All students have an opportunity to make use of their strengths and to help each other with their weaknesses. Assessment of students includes presentations of individual and group projects, openended individual essay-type tests, using scoring rubrics, the evaluation of student conceptions and pre-conceptions with concept maps and other methods, and the building of a portfolio with authentic work kept in printed and video formats.

Doing Earth Science Investigation Before Learning Basic Knowledge in an 8th Grade Earth Science Class.

Mary Colson, Moorhead Junior High School, Moorhead, MN USA. Russell O. Colson, Moorhead State University, Moorhead, MN USA.

Secondary earth science curriculum is often dictated by a textbook which provides the teacher with the information, the order of lessons, the worksheets and lab activity sheets. Students usually survey a breadth of topics without having the time to delve deeply into a few selected topics as teachers work to "get through the textbook" and cover all the important material. Because secondary schools teach the general population, geoscience educators have a responsibility to present science not only as the accumulated knowledge of generations of scientists, but as a way of examining and understanding the world we live in.

I have developed an environmental service-learning project to encourage my students to observe, to think about, and learn about our local area: the Red River Valley of Western Minnesota. My students have "adopted" an underdeveloped city park located along the Red River of the north to study and are working to develop it into an accessible natural area. Students learn about drainage basins, river flooding and river features, geologic history of the Red River Valley, glacial processes, trees and birds of the riparian forest, topographic maps and orienteering.

Under the umbrella theme of studying a local region, this sort of project can be used to teach some fundamentals of Earth and Life Science. Take the following example of a typical lesson. Flooding is normal every Spring in the Red River Valley and is therefore a concern of residents of the Valley. My students use past flood crest data and plot the 50, 100, and 500 year floodplains on a topographic map of the park and town. We discuss if student's homes are likely to get flooded yards or wet basements. We discuss why people build on a flood plain. We discuss why flooding is an inevitable problem in the Red River Valley. We take a Spring field trip to the park and see how much land is underwater and compare this with our maps of past floods. When the floodwaters recede, we go back and look at what the water left behind. This project not only allows students to investigate but also provides them with opportunities to work together and to develop their writing and communication skills. Students built and now maintain a self-guided nature trail along the river; they also create trailhead displays, write or update the trail guide, and maintain bird boxes. The common thread that connects these topics is "our" park.

How effective is this kind of curriculum? If we sacrifice breadth for depth, do we nurture scientifically literate teens? We have developed an Earth Science Basics test that seeks to test if this type of curriculum helps students to learn the fundamental concepts of geology. We have tested 120 eighth grade students; 60 are enrolled in an accelerated activity-based earth science class and 60 are enrolled in the class described above. The same test is being used in a nontraditional Earth Science college class. Students take a pre and post test; results are available from the authors.

Tropical Rain Forests Forever: Earth System Science with Constructivist Instruction Strategies.

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The Tropical Rain Forest theme easily lends itself to constructivist instruction strategies enabling students to work in traditional labs, but perform experiments of an integrated nature, using historical investigations and technology, including the internet. Because of the rapid growth of the world population and demands for natural resources, many tropical rain forests are threatened. We have destroyed large areas by clearing land for farms and cities. Mining, ranching, and timber projects have added to the damage. Scientists estimate that 50 million acres are destroyed annually and predict that within the next 25 years one-quarter of all biological diversity in the world (more than a million species) will vanish with the destruction. The last extinction of this magnitude occurred with the extinction of the dinosaurs 6.5 million years ago. We need to protect what we still have.

Integrated sciences in this thematic unit ensure that students realize Earth is one, a fragile system where everything is related and depends on everything else. Constructivist lab activities, experiments and research in local libraries and on the internet are designed for student input with direction by general science teachers. The transition from traditional courses requires curriculum planning and teacher training, but neither takes extra time in the classroom nor additional funding. Tropical Rain Forests Forever can be covered in allotted science time in the classrooms, labs, outdoor areas, in the field, and on electronic field trips. Topics can be covered at school, in local libraries, and at home. All students, regardless of ability and aptitude, will be involved in helping to design curriculum with their experimentation, predictions, and problem solving.

Even though tropical rain forests may be at a distance, we all have natural resources in our immediate area to protect and compare with the rain forest. Issues such as acid rain and global warming relate to us all. Every student needs to learn about plant and animal life, minerals, cycles, land forms, atmosphere, and oceans, in order to aid in the safekeeping of our planet. This module offers a wealth of areas which will enlighten students regardless of locale. Some experiments include: Photosynthesis and light measurement; Vapor transpiration, the water cycle, and water testing; Carbon dioxide emissions and acid rain; Fertile soil, soil erosion, and soil contaminants; Historical natural resource investigations; Medicines and extracts; and Weather, clouds, and atmosphere. Individual and group topics and activities include: Debates/panel discussions representing interest groups; Historical essays on conservation and social implications; Habitats and adaptations; Population growth and dynamics; Protection agencies; Carbon and nitrogen cycles; Migration of songbirds and butterflies; Food webs—bats, nonhuman primates, elephants, and microorganisms.

This module may be taught in the amount of time available with one common theme. To quote George Schaller, one of America's most distinguished naturalists, "As an ecologist, you walk around the world and see the wounds and the scars, and your spirit just cries. But then you see the future, and you fight on, with hope. Nothing is ever safe. We have to protect what we still have."

Earth Science Student Teachers.

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Earth Science Student Teachers (ESST) is our program which trains high school students as an outreach effort to provide elementary classes with Earth Science and Earth Systems enrichment. Secondary Earth Science students organize interactive laboratory plans and coordinate their efforts with cooperating primary instructors for curriculum articulation, as well as with science professionals and instructors for content accuracy. During the two years this program has existed, approximately 50 ESST have presented lessons to over 1,000 emerging Earth Scientists.

The main objectives of this program are to enhance the Earth Science curriculum, teach stewardship of natural resources, and share academic Earth Science resources and knowledge. Based on teacher appraisals, all objectives have been met and far surpassed. Some of the lessons which have been repeatedly requested by teachers as well as their students are Fossil Safari, Weather Measurements, Trash-a-Thon, and Big Crystals.

Our ESST, using the high school's references and resources, prepare and organize lessons for elementary students. This process includes making arrangements with a cooperating teacher and checking content with a professional as well as having permission slips signed. Science professionals (e.q. oceanographers, meteorologists, and science professors) are to ensure that the presentation will be interesting and scientifically correct. The student teacher then travels to the cooperating teacher's class to conduct the presentation. While the ESST student conducts the presentation, the cooperating teacher evaluates and makes recommendations. Participation in the ESST program counts as a major project or test. ESSTs are required to evaluate themselves and have feedback from the cooperating teacher (all of which has been very positive). Each of the cooperating teachers has asked us to return. The program has been conducted in 10 schools in two counties. Our ESST students have mainly targeted grade levels K–3, placing an emphasis on the age difference. The high school students who have participated in this program have ranged in academic ability and include grades 9–12. The ESST gains knowledge though intensive preparation.

As a result of the program, primary students and teachers have taken field trips to West Carteret High School. Field trip investigative activities include hydrology (95–96 ES classes installed three ground water monitor wells), exploration of 10 tons of fossil material (from Lee Creek PCS mine Aurora NC), and weather observations with two types of weather stations. The most important outcome is that all participating students are made more alert, observant, and attentive, about the Earth. Some secondary students, as a result of participating in this program, have chosen careers in education and in science. Three ESST's have taught their younger siblings. Some participants have returned to their own elementary or primary school teachers simply to say "Look, I'm doing all right" and "Thanks." Over a thousand young students have experienced quality Earth Science activities. The program has taught our secondary students a new appreciation for science, education, and the world around them.

An Integrated R–12 Earth Science Curricula Model.

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Enrollments in senior secondary Earth Science courses around the globe appear to be falling. The problem was highlighted by many presenters at GEOED I, and does not appear to be improving. A question often asked by University faculty heads and industry is "How do we encourage students to undertake studies in Earth Science?"

Most primary teachers experience the enthusiasm young children display when confronted with pictures or videos of volcanoes, earthquakes or dinosaurs. Children enjoy collecting rocks and fossils, and are keen to learn about them. When children reach secondary school, Earth Science is an area often overlooked, with curricula being dominated by biological and physical sciences, and they lose touch with the area that once interested them. If they are lucky they may have some Earth Science in Geography courses.

Recently in Australia, implementation of National Statements and Profiles covering eight learning areas has occurred in most schools. Science is one of these learning areas, and within this Statement is a strand *Earth and Beyond* primarily covering Earth Science topics. This new approach ensures that each child will be exposed to Earth Science throughout their 10 years of compulsory schooling.

The problem of how to encourage senior secondary students to undertake studies in Earth Science still remains. In South Australia a new Year 12 Geology syllabus has been introduced. This has been ten years in the making and many people from the secondary and tertiary education sectors and industry have been involved in its development. The new course includes traditional solid Earth topics, but is followed in the second semester by applied topics such as geological hazards, sustainable development and ocean/ atmosphere interactions. These changes have been made to appeal to students wishing to study a science AND to become more informed about current environmental issues. The areas include water resource management, past and future effects of asteroid impacts, global warming/cooling cycles, ozone depletion, and impacts of mining.

As Earth Science educators we need to keep our curriculum in line with societal needs, to provide access to current research and ideas and to help students understand that studies in Earth Science will provide them with skills and ideas appropriate to life in the twenty first century.

Evaluation of Earth Systems/Earth Science Curricula.

Mary Bishop, Saugerties Junior/Senior High School, 151 Albany Avenue, Kingston, NY 12401 USA.

Since 1970 New York State has had a successful Regents Earth Science Program. Today, however, that program does not sufficiently address the needs of the students of the 90s. The Earth Science Program Modification, of which I have been an integral part for seven years, has proved to be a much preferable vehicle of instruction.

The major additions to the existing configuration of the syllabus include

- an expanded lab performance component which stresses several essential scientific skills that should be mastered by each student.
- a project which requires each student to make and record scientific observations, interpret the data, and communicate the findings, and
- written (free response) interpretations to Earth Science related situations and problems.

This multifaceted assessment offers students more opportunities to demonstrate the mastery that they have acquired than the older strictly multiple choice Regents exam offered. In the written responses students must use complete sentences which we have used to integrate English practices into Science. The project portion engages students in "doing Science" not just hearing about it. The skills that are tested on the performance test at the end of the year are those that are used throughout the year during the lab sessions which happen at least two periods a week. Analysis of the scores from the last three years show that the percentage of students achieving mastery level scores (85 or more) has increased significantly.

One major change has been made in the content area. That is the addition of a unit entitled Environmental Awareness. It includes such topics as the interdependence of Earth's living and non-living systems, pollution of Earth's water, and living in balance with our natural environment. I believe that all of us who have been using this program modification have strived to weave this unit throughout the year. The eight other major units are: Measuring the Earth, Minerals and Rocks, The Dynamic Crust, Surface Processes and Landscapes, Earth's History, Meteorology, The Water Cycle and Climates, and Earth in Space. These areas are called the core and are the basis for the statewide Regents exam. In addition, the following extended areas may be included at the discretion of the individual teacher: Rocks, Minerals and Resources, Earthquakes and the Earth's Interior, Oceanography, Glacial Geology, and Astronomy.

Systematization in Teaching Method of Outdoor Education.

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We can capture student interest in learning science by relating concepts and ideas to the environment in which they live. They can see science as it relates to other school disciplines such as social studies and history. Outdoor learning effectively relates to the variety of interests and abilities of students because of the variety found in nature. Through assistance from the curator of a science museum, a specialist from the environmental protection society, and the school district's nature specialist, I was able to adjust my curriculum in biology and geology to incorporate the outdoor learning. This allowed me to integrate science with a variety of other subjects, including the study of the Japanese language and of English, cooking, fine art and some technology. I will continue development in my school with the assistance of those cited above, plus a local university professor.

The Event-Based Science Way To Teach Science.

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Event-Based Science (EBS) is a whole new way to teach middle school science. Each unit begins with television news coverage of a real event. After discussing the event, students are given a challenging task to do. For example, Oil Spill!-an EBS unit on ocean-system concepts-begins with CNN coverage of the Exxon Valdez spill into Prince William Sound. In Oil Spill! the task is to investigate a port city with respect to its suitability as the site for a new oil terminal. Concepts of tides, currents, marine life, and topography of the harbor are learned and immediately applied by students as they select among competing sites.

Event-Based Science books are unlike regular textbooks. An EBS book tells a story about the event; it has newspaper articles about the event, and essays that explain scientific concepts involved in the event. It also contains open-ended laboratory investigations for students to conduct in their science classes and interdisciplinary activities for them to do in English, math, social studies, and technology education classes. In addition, an Event-Based Science module describes in detail the real-world task that is the focus of the unit's work. The task is always done by teams of students, with each team member performing a real-life role as they complete an important part of the task. Interviews with people who actually serve in those roles are scattered throughout the Event-Based Science module. Middle school students who experienced the event tell their stories throughout the module too.

A review of middle school instructional materials recently published by the National Science Foundation cited Event-Based Science for its:

- strong inquiry focus
- use of authentic assessment
- student-centered design
- interchangeability of modules, and
- relevant tasks

Earth Science titles currently available from the Event-Based Science Project include: Oil Spill!, Hurricane!, Earthquake!, Toxic Leak!, Flood!, Asteroid!, Volcano!, Gold Rush!, and Tornado!

Session Summary IC: K–12 Curricula.

This Summary was prepared by William Hoyt, Theme Session Coordinator. Discussion leaders were Hoyt, Masakazu Gotoh and Dan Jax.

K–12 issues were the subject of this session. One breakout group focused on using the team approach of assembling many teachers together in K–12 settings—primarily middle school and high school settings—to study systems. Watershed systems were featured in a number of presentations. Most of these groups of teachers had gotten together in a common planning period, which requires administrators to schedule their planning times together each day. This allowed the teachers to have regular quality time to get to know each other, to understand what was good about things they were doing and what they could build upon as a team. One report from a teacher team in Idaho said that 85% of their money for field work came from the state. Many of the teams described how they would send some teachers out into the field with students while other teachers would stay and work on laboratory and computer activities. All of them agreed on the need to clearly identify the problems they wished to study; as they approached solutions, they had to allow time to debrief those solutions and to share them with each other. The teacher teams spoke favorably of integration of more subjects than just science or math or social studies. In fact, one team included an English teacher.

A theme that emerged in many of these discussions was the need to find ways to broaden the curricular attraction for studying systems. Engineering schools now spend a lot of time and energy trying to identify engineering degrees which study systems, because in most cases that's what engineers are hired to do—work on some kind of a system, not just electrical aspects of a Boeing 747, but all of the physical and mechanical systems that go into that. Similarly, teachers were very excited about working with each other after they had done it. Before they had done it, they were scared to death—a lot of sweat, a lot of concern, a lot of issues of "Can I really work with this person if they don't understand my discipline? And I certainly don't understand theirs." Once they started doing it they were much more comfortable engaging in that process.

The second element suggested by that group was that we need help on grantsmanship: how do we

- write proposals for grants
- acquire nonmonetary support
- find out about the variety of funding sources
- get time to work together and generate ideas that can be funded?

Another focus group met and discussed "How do we assemble a middle school earth science curriculum?" In the U.S. many approaches are used. Many people are looking for kits and cookbooks that integrate science. We had a lot of discussion about the variety of sources and materials that are available but came to the consensus that there really is not a single place to go to get everything you need. Communities need to define what is important in their local setting and that's very difficult to do. It requires time, energy, and lots of support. The folks who had been successful in doing this described high levels of support from their administrators to do so, and they required that in writing before they started.

The second group reported that they had discussed two major issues: one was the responsibilities of students as learners. It dovetails with the second, the motivation of the students. The approach that they suggested was that in the student's daily life—what they do in school, in classes, what they do in home, what they do with their families, what they do in their jobs (if they hold jobs), what they do in taking examinations—all of those elements of their life need to be part of the student's responsibility to learn. They need to understand and have full disclosure about their educational training and how the final exams will use elements they have been learning through the entire semester. As we go into this phase of having the student take the responsibility of learning, a teacher—and the learner—sets the agenda for learning. A very different balance between student responsibilities and the responsibilities of the teacher emerges.

The last group from the afternoon session wanted to know what the common elements of successful curriculum development processes were, if they require problem solving skills—learning how to think, identifying the habits of mind again—a similar theme from what we had before. They suggested that the major themes from the National Science Education Standards (see Rodger Bybee's address) were not setting the agenda for curricula but were appropriate for what we needed to do. Their last comment had to do with the process of change. They emphasized how hard that process is within communities. How do we lift students to a higher level of performance and engagement? Those attributes are related to each other and are involved in the change process. The group suggested that to undertake a change process we need change agents. We all have seen them and used them, and perhaps been some of them, but these agents need to have support from their administrators to be successful in implementing change.

Session ID: K–12 Programs

Norikazu Osumi and Judith Riestra, Moderators

In many areas of the world, geoscience education has benefitted from state and national curriculum restructure efforts. Reports from four continents and the Pacific Rim islands describe such impacts, most of which hold the promise for positive change. Presentations in this set dealt with the need for separation of Earth systems education from physical geography, a need for training and retraining teachers for new ways of teaching, and methods for integrating content. The session papers reinforced the importance of regional/local information for relevance to K–12 students.

Maps Across the Curriculum: A South Carolina Model.

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The SC MAPS project (South Carolina Maps and Aerial Photographic Systems) is an award winning middle school earth science curriculum package produced in collaboration with a variety of state agencies, geoscientists, and educators. It was developed originally to help students visualize relationships between South Carolina geology and statewide patterns of land use and development by interacting with a variety of cartographic products and remotely sensed images. These products range from topographic and shaded relief maps to high altitude photographic and satellite images which together serve as the framework for hands-on student learning activities.

Each of the five major landform regions of South Carolina is illustrated by one or more local study sites representative of that region. Each site highlights areas of geological or historical interest and contains features that are clearly visible on high resolution infrared aerial photographs and/or infrared satellite images, as well as on topographic maps. A separate set of special purpose maps and images of the entire state provides information on topography, geology, soils, land use/land cover, and cultural features. Middle school students use classroom sets of these cartographic products, laminated for repeated student use with wipe-off pens, to investigate the influence of geological and cultural processes on landscapes of the past, present, and future. A Teaching Manual contains narrative background information and sets of student activities and exercises which are keyed to the various cartographic products.

The expanded SC MAPS materials model current middle school initiatives towards providing interdisciplinary team approaches to learning. Using the geological framework of South Carolina as the basis for thematic study, new curriculum components emphasize social studies (historical and economic data), mathematics (computational and problem solving skills), language arts (storytelling and cultural diversity), as well as science (environmental concerns). Pedagogical strategies such as cooperative learning, constructivism, and performance-based assessment are incorporated within the program. The emphasis on local and statewide concerns stimulates student interest and involvement and provides common ground for interdisciplinary problem solving.

Integrating Earth Systems into the Utah Statewide Science Core.

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The State of Utah has revised the Secondary Science Core that guides science instruction throughout the state. One important feature of this new Core is the introduction of an Earth Systems Science course at the ninth grade level. Earth, space, life and physical science are integrated in this year-long course that is targeted for all students. The curriculum course description was developed using Project 2061's *Benchmarks for Science Literacy* as a guide in determining appropriate content and process skills. The course standards and objectives place a strong emphasis on students engaging in active learning experiences.

This ninth grade Earth Systems Science course provides a working model of a statewide effort to integrate an Earth Systems instructional approach with systemic education reform. This is particularly significant because education reform and Earth systems/environmental education generally do not connect with each other. Most proponents of Earth Systems education do not take advantage of systemic education reform efforts in implementing their programs. Similarly, most education reform efforts do not realize that Earth Systems education provides an excellent venue for implementing the reforms that they propose.

The Utah Earth Systems Science course embodies many of the components of systemic reform. It is part of the statewide program for science education and will be included in statewide assessments. A broadly based collaborating network is involved in developing lessons keyed to the core, training teachers throughout the state, disseminating information about and resources for the course, and establishing a web site to specifically support teachers and students working with this Earth Systems Science course. Collaborators include teachers, staff from the Utah State Office of Education, professors, scientists, resource agency personnel and the WestEd Regional Education Laboratory. In addition, the integrated content and the emphasis on process skills, student inquiry and personal relevance all support the methodologies and goals of education reform.

Earth Science Education in the Philippines through SMEMDP.

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Science and Mathematics Education Manpower Development Project (SMEMDP) commenced in 1994 as a cooperative project of the Republic of the Philippines and the Japanese government through the Japan International Cooperation Agency (JICA) to upgrade Science Education in the Philippines. This five-year project includes (1) the dispatch of Japanese Science Education experts, (2) counterpart training, i.e. training of Filipino educators in Japan, and (3) provision of science equipment and facilities. As part of the SMEMDP, the National Training Program for Earth Science Teachers, among others, was held in 1995 at the University of the Philippines' Institute for Science and Mathematics Education Development (UP-ISMED). This subprogram was supported by the Department of Science and Technology, Department of Education, Culture and Sports, and the Commission on Higher Education. The staff of Earth/Environmental Science Education Workgroup of UP-ISMED who worked closely with the assigned experts became the trainers. About sixty (60) earth science teachers, who were representatives of the 15 regions of the country, received the national training to become trainers for their respective regions.

Science Education in the Philippines
h SMEMDP
CANO Miguel MAEDA Yasuo

Those trained on the regional level then became the trainers for the school division level. Source books for teachers were developed to facilitate the training on both the Regional and Division level. The project is still in its early stage, yet it has yielded some positive results as manifested in the enthusiasm of the teachers who received the training. The program aims to enhance the potentials of Filipino educators to be trainers, not only in the Philippines but to some other countries as well, especially in the Asian region where (1) they can communicate well in English and (2) they live on "tectonically beautiful" islands being located along the Pacific Ring of Fire, next to the Pacific where typhoons are born. Thus, they have a great exposure to natural geophenomena. The outcome of the project will greatly influence the development of the curriculum for the 21st century in Earth Science Education in the Philippines.

Earth Science Education in South African Schools: Is the Tide Turning?

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Despite an economy which is dominated by the Mining and Minerals Industry (accounting for 42% of all exports in 1995), South Africa produces fewer than 100 Earth

Science graduates per annum, a figure which does not meet current Industry needs. This situation reflects a lack of awareness of career opportunities in Earth Science among school-leavers, brought about by two factors:

1. In contrast to the Life, Physical and Mathematical Sciences, Earth Science does not exist within the current National School Curriculum as a distinct subject. Earth Science topics are, instead, incorporated as a minority component within the Geography subject area, which is dominated by Human and Social Sciences.
2. The overwhelming majority of Geography teachers nationally (over 90%) are trained exclusively within the Humanities field. Their lack of science qualifications negatively impacts the Earth Science curriculum component, with two consequences. Students with an interest in science are not made aware of the scope and career opportunities within this field, and a high proportion of students registering for Earth Science at the tertiary level are underprepared relative to those registering for other Science subjects.

Faced with closure due to extremely poor staff-student ratios (national average 1:5), University Earth Science departments have recently sought to address these problems by, *inter alia,* providing short courses to Geography teachers and information talks at schools, and by promoting Earth Science related extracurricular activities; however, these measures cannot realistically redress the imbalance within the existing curriculum.

Following the 1994 transition to democracy, the South African Government has embarked on a comprehensive restructuring of the national school curriculum, aimed to commence in 1998. Intensive lobbying by the Geological Society of South Africa and the Department of Geology at the University of the Witwatersrand has led to the incorporation of Earth Science as a component of the Natural Sciences, one of the eight learning areas identified. For the first time, students will be able to study Earth Science together with the Life and Physical Sciences.

The National Education Department has adopted the outcomes-based approach currently in use in countries such as Australia, Holland, New Zealand and Scotland. Specific outcomes adopted by the National Committee for the Natural Sciences learning area are aimed at the acquisition, development and application of knowledge and skills which will have relevance both within everyday life and for socioeconomic development, as well as emphasizing an appreciation for, and the judicious management of, natural resources.

We reported on the progress in developing the Natural Sciences curriculum for Grades 1–9. One of the aims of this work is to emphasize links between the Earth, Physical and Life Sciences, which is in line with the philosophy of Earth Systems Science. A fundamental change in teaching strategy will also be implemented to move away from the current, content-driven, approach to a skills-acquisition approach. The emphasis will be on process-oriented learning. It is envisaged that comprehensive teacher restraining programs will be needed to overcome initial difficulties with implementation of the new curriculum. The challenge of applying this in a multi-cultural society with a legacy of strong imbalances in the quality of teachers and education is also being addressed.

The System of Geological Concepts in the School Physical Geology Curriculum.

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Earth science (geology) today is not an independent school subject in the present-day Russia. It disappeared from school curriculum as an independent discipline in the 1950s. But before that, in 1920s–1930s, geology became a compulsory subject in the school curriculum. It was the time when there appeared textbooks of geology for schools, methods of teaching geology, geological museums and special classrooms (Nesterov, 1996). Now some geological ideas are considered within geography courses.

Students' general knowledge of rocks, minerals and geological processes (erosion), gained from the natural study course (4th–5th grades), is used to help form the geological notions in the elementary course of physical geography.

The system of geological concepts in the elementary course of physical geography (6th grade) lies in the topic "Lithosphere": the inner earth's structure (the core, the mantle, the crust), igneous, sedimentary and metamorphic rocks, the earth's crust shifts, earthquakes, volcanoes, hot springs and geysers. Besides, students are supposed to form a notion of mountain and plain changes caused by inner and outer processes. Students study their local relief and rocks' distinctive features during their country excursions in the fall.

The 7th grade course "Geography of the Continents and Oceans" contains geological concepts. Section one "Lithosphere and the Earth's Relief" investigates the main hypotheses on the origin of the continents and deep-sea trenches. Relief is viewed as a result of the inner-outer processes interaction. Every topic on continents in Section "Continents and Oceans" deals with studies of the relief in interrelation with the geological structure. The geological history of the continents' formation is regarded as the foundation for the origin of the present-day main relief and organic forms.

Section "General characteristics of Nature" of the course "Geography of Russia" contains a large group of geological concepts. Here the notion of geological years-numbering is introduced for the first time. Much attention is paid to studying the folded and platform areas as well as minerals found there, the earth's crust shifts, earthquakes and volcanism, and ancient and contemporary glaciation. Studying the native land geological structure and mineral specifics is also provided for. Besides, section "Geography of Homeland" includes the notion of the mineral resources economic evaluation.

Study of the relief and mountain rocks of the region is fulfilled during the excursion teaching in nature. During the excursion, rocks are studied visually. Depth of learning depends on the knowledge of the teacher. Volume of knowledge about rocks is not determined in the program. Relief is considered as a result of interactions of internal and external processes. Relief is viewed in interrelation with the geological construction in the section "Mainlands and Oceans" in every topic separately.

In the contents of knowledge about geological eras, the basic concepts of geological evolution are included as well as distinctive notions of the plant and animal world. A big group of new geological concepts is introduced into the course "Geography of Russia" in the part "General features of nature." Here the notion of relative and absolute geological age is provided. The folded and platform areas are studied; connected with them are mineral deposits , movements of lithosphere plates, earthquakes and volcanism, both ancient and modern.

In the 1960s, visual study of characteristics of basic minerals and rocks (colour, brilliance, hardness and others) was envisaged in the geography curriculum. Some practical classes were held to provide such a study. At present these practical works are held only in the optional course "Geology." The greater attention is paid to ore deposits (ores of ferrous and non-ferrous metals). Direct work on the determination of rocks' locality is usually realized when studying home regions. Concepts of quaternary is required for explanations of origins for the most important forms of the relief.

Regrettably, all of the most important concepts of the nature of Russia are considered from the positions of the theory of glaciation. The results of the sea transgressions in the quaternary period are omitted. Strategy of economic estimation of natural resources, part of "Geography of home land," is performed in two stages: qualitative estimation and quantitative.

Recommendations on the improvement of studying the geological concepts in the courses of physical geography are made on the base of conducting analysis:

1. Deeper studies and understanding of the evolution of the Earth in the secondary school is based on the notions of geochronology. The students begin to study the topic in the 6th grade and go on with it in the 7th and 8th grades. In the 6th grade, the study of the nature of the Earth's crust is the main topic. In the 7th grade, the main attention is drawn to the history of development and introducing the notion of lithosphere plates. In the 8th grade these ideas are used for a deeper study of the history of Russia.
2. The program of physical geography needs to enforce the role of field studies on the basis of the notions of the groups of rocks, geological structure and using the knowledge of the home region in solving the ecological problems.

The modern program for state schools proposes the carrying out of geological excursions. Excursions are very valuable for education because they give a good opportunity for pupils to get vivid, imagebearing, and substantial impressions by natural objects and phenomena, trace back the conformity of development of natural complexes. Excursions also can be very useful for the ecological education of pupils on the local materials (Kadenskij, 1963). The geological objects have their special value for education. It is not easy to see them in usual life, but pupils who have never seen the phenomena of the stratified bedding of the rocks, the erosion of the river banks or the coming of dunes on an excursion cannot imagine them deeply at the lesson. So it makes special sense to include geological excursions in the educational process.

The volume of geology within the school geography curriculum enables students to shape a certain system of geological ideas. But such a system is rather fragmentary and needs improving. Such a system does not solve the problem of the students' geological illiteracy (Mayer, 1991). Of course a lot of learning problems can be solved easily if teachers are ready to do it (Carpenter, 1993).

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The Study of the Geological Heritage in the System of Earth Science Education.

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One of the sharp problems of modern geology in conditions of active anthropogenic changes of the Earth is preservation of our geological heritage. Rare geological outcrops, localities of minerals, gemstones, paleontologic remains and other geosites of special scientific and historic importance may be announced as natural reserves, national and natural parks, and local monuments of nature. All of these geosites represent the geological heritage. The objects of geological heritage are the main material base of geology.

The lack of knowledge about geological heritage leads to destruction of valuable objects. For example, the unique locality of the late Permian insects "Tikhie Gory" (object of the 7th IGC) was lost after the flooding of Kama Reservoir. Everyone should understand that the slightest damage could lead to irreversible losses for the future. So the study of the geological heritage in the system of geoscience education is the necessary condition of its protection.

It is important to teach pupils to protect our Earth heritage beginning with primary school. One of the main tasks of a teacher is to cultivate in school children the care and love of nature on the base of special knowledge. In universities it is appropriate to study the geological heritage as a special geological discipline. The teaching should involve the theoretical bases of study of the geological heritage with field excursions and practices on the geosites.

The students should learn to assign a geological object to the geological heritage. In this case they must use the following criteria: the best expression of geological phenomenon; significant variety of its manifestations; its uniqueness (or on the contrary typicalness for the region or for the world); the first find of phenomenon and its historical significance in the development of geology and mining.

The geological heritage has been classified into types and subtypes according to specific geological disciplines, such as stratigraphy, paleontology, mineralogy, etc. Usually we have geosites of several types. The geological heritage is being ranked into levels of significance using geological criteria. There are four such levels: global, subglobal, regional and local. The official status of a geosite (world, federal, regional or local) is to be defined according to its significance level.

The common effort concerning the problem of protection of geological heritage became much more active all over the world. The First International Symposium on the Protection of the Geological Heritage was held in 1991 in Digne, France. In 1993 in Cologne (Germany) the European Association for the Conservation of the Geological Heritage (ProGeo) was established. One of the tasks of the Association is the compiling of Global Indicative List of Geological Sites.

The knowledge about geological heritage allows for a combination of exploitation of mineral resources with the preservation of geological phenomenon in natural conditions for their subsequent study; it allows for the choice and organization of scientific geological excursions, student and school practical training.

Earth Science Education in New Zealand.

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Historically, Earth Science and Astronomy have never occupied a position as powerful and independent as Physics, Chemistry, Biology, Geography and Social Studies in our schools. Like many other countries, Geology and Earth Science is essentially derived from a British curriculum model and associated with physical Geography courses. However, with the revolution in our understanding about how the Earth works, the knowledge explosion could not be accommodated as part of physical Geography courses. Similarly, traditional Physics, Chemistry, and Biology syllabi could not keep pace with nor accommodate our burgeoning understanding of topics in paleontology, geophysics and geochemistry.

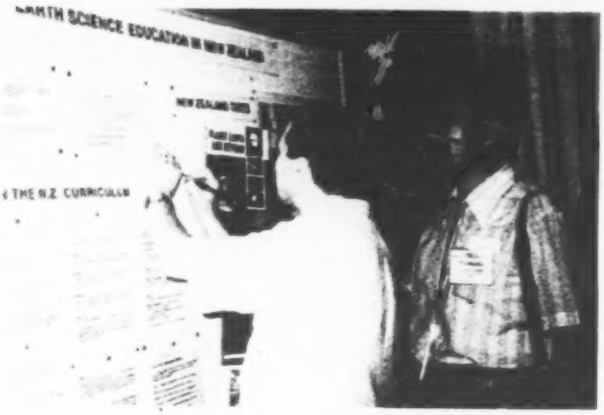
In New Zealand, Earth Science is taught within the 'Planet Earth and Beyond' strand of the national science curriculum and is effectively compulsory up to year twelve (age 15 or the end of third year at a secondary school).

The Science curriculum caters for year one to year thirteen (age 5 to 17), and is presented as strands of learning. Each strand has detailed achievement aims and objectives for each year level and is assessed either by external examination, internal assessment with national moderation, or by unit standards.

The Science curriculum has the following structure:

A. INTEGRATING STRANDS= Making sense of the nature of science and its relationship to technology

B. CONTEXTUAL STRANDS= Making sense of the living world, making sense of the physical world, making sense of the material world, making sense of the planet earth and beyond.


EARTH SCIENCE EDUCATION IN NEW ZEALAND
THE N.Z. CURRICULUM

Other areas in which Earth Science topics are dealt with include, the social change section of the Social Studies curriculum, senior Physical Geography (years twelve and thirteen), and senior Biology. Astronomy on the other hand is taught almost exclusively within the junior Science curriculum with minor connections to senior Physics. Earth Science (usually as Geology) is taught at all seven universities.

The drive to make Science more 'relevant' to individuals, society, and technology has not escaped the 1993 development of 'Science in the New Zealand curriculum' as one of the seven essential learning areas. This 'new' Science curriculum initiative is part of major reforms in New Zealand schools designed to help meet the needs of a rapidly changing society and economy. The full impact of these reforms is yet to be felt, and there is currently much anguish and debate concerning the introduction of a 'seamless' education system and a hotly debated assessment procedure called 'unit standards.' The final form of assessment and curriculum delivery is yet to be seen, but workload issues, politics, and funding are never far from the surface.

Up until 1993, Earth Science education in the secondary school was a relatively minor part of the junior Science curriculum and usually simply put off. This was largely because of inadequate resources, insufficient numbers of Earth Science trained staff, and lack of time. With the new Science curriculum, the status of the Earth Sciences has greatly improved but the problems of staffing and implementation remain the same. Earth Science is now an equal partner with Physics, Chemistry and Biology and is required to be taught up to year twelve. It is becoming more a part of school science 'culture.' However, the subject does not enjoy the same status at senior high school level. To study Earth Sciences at senior level a school must offer the general Science course where Earth Science makes up a quarter of the year's work. Most schools do not offer senior Science. It is beyond the scope of this abstract to discuss the reasons for this, but problems relating to resources, staffing, subject competition and curriculum history and philosophy are some basic causes. Earth Science topics also have some curriculum connections with year twelve and thirteen Biology (evolution and genetics), and years eleven, twelve, and thirteen Geography ('natural hazards,' 'natural landscapes,' and 'natural processes').

Although the status of Earth Science education in New Zealand has improved greatly, there is still a long way to go for it to be a full part of science 'culture.' For this to occur, resources, training, and adequate funding are vitally required.

It is important that an 'educated' population knows about the place of 'their' planet in the universe, that they know how it works and what people do to it. The debate of how to effectively deliver what is relevant for tomorrow's students of Science will continue to evolve. Earth Science must continue to be a vital part of that education.

Earth Science Teaching in Venezuela: A Follow-Up

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The Earth Science Curriculum implemented in 1992 as an experimental curriculum has been followed up in different aspects. The curriculum evaluation model is framed in the qualitative paradigm since it is this approach which gives more insights about how actors comprehend it. During this time, teachers and students have been interviewed in order to get information. These results are and will be used to restructure this curriculum. Since 1992 some goals have been achieved which are reported in this paper.

1. Teacher's attitude towards science teaching. This test was applied to the participant's teachers at the beginning of the trial, in September 1992. One year later they were retested. The results were analyzed with non-parametric statistic, and it was shown there were no significant changes between the two years. Interviews with teachers show that they felt very insecure with the new curriculum, so it was decided we would wait a longer period of time to allow teachers to become familiar with it. The test was to be applied during 1996–97.
2. The structure and sequence of units are a problem for teachers and students to understand the Earth as a system. The sequence goes from macro to meso and micro levels of interactions, and it puts emphasis on the features of the Earth's system. The most difficult level to understand is the meso level. Since teachers are not used to working with interactions between geospheres, it is easier to work with very general or very specific aspects of the Earth in separate ways. Atmosphere and hydrosphere interactions and lithosphere and mantle interactions are aspects of the Earth unknown by teachers, thus they are difficult to deal with. At the root of this problem lays the fact that Earth as a system is not a concept of a teacher's conceptual frame.

3. One of the most attractive aspects of student's materials are the readings related to Earth Science Professions with emphasis in Venezuela's needs.
4. One of the goals successfully met is the organization of university teachers in order to be involved with curriculum development. This effort should continue to be strengthened. There have been regional seminars, conferences, and workshops aimed to get working teams between university and secondary school teachers. In Venezuela we have a national curriculum and the dissemination model used is the center to periphery. This means that there is little space for university teachers to develop new curriculum, although this is not a necessity of secondary school teachers. What these teachers feel is currently needed is service training for them in order to gain confidence about the new approach of the Earth Science Curriculum.

A GeoScientist in my Class?

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PROGRAM DESCRIPTION

This innovative science program invites children to discover the real world of science. The hands-on science activities are integrated to a certain extent with all subjects of the curriculum. This integration helps LEP students develop basic science process skills, learn science concepts, improve and expand Spanish and English vocabulary, improve written and oral communication skills, and encourages social interaction through group activities.

Begin with a KWL chart to plan the lessons. To motivate students, read and discuss *The Magic School Bus Inside The Earth*. Then, begin a vocabulary list and explore fictional and nonfictional parts of the story. To understand the abstract concept of layers of the earth, groups of students compare a peach to a drawing of the earth's interior. They also take an imaginary trip to the center of the earth on a school bus. Students describe the trip in their "Geology Journals." After this trip, each group makes a model of the inside of the earth with four different colors of clay and presents the model and description to the class.

A trip through the earth's crust allows the students to learn about some of our natural resources (soil, rocks, minerals) and about how important it is to protect these resources found near the earth's surface. The students observe, describe, and classify various types of soils that come from a garden, sandbox, or backyard. A class discussion about the importance of soil utilization and conservation follows.

To study rocks and their mineral components, students bring "pet rocks" to school. Students observe and describe each rock's properties (color, texture, shape) and they measure its mass and perimeter. Students describe these properties in their "Geology Journals." Each group prepares a rock collection. To further investigate the composition of a rock, students "Rock and Roll" (to the tune of *The Dinosaur Bop*) some homemade rocks in water to observe how rock materials separate and settle. Students record observations and results. From this experiment, students discover that rocks are made of minerals. To conclude the program, students research and give oral reports about various minerals and ways to use them. Each student receives a "Super Geologist Award" upon successfully completing the program.

THE PEOPLE

This program has been successfully used in a third-grade bilingual class and can be implemented in third- through fifth-grade ESL, regular, or gifted and talented classes. The program only requires the classroom teacher as facilitator. A geologist can be invited to come and talk to the students about his/her job.

MATERIALS

Different types of soil, coffee can, plastic cup, peach, knife, dental floss, homemade rock, balance, magnifying class, metric ruler, tape recorder, music, one set of weights for each group of students.

OVERALL VALUE

This is an exciting and motivating program that: 1) promotes science literacy, 2) links classroom activities with real-life applications, 3) teaches critical thinking skills that are so important to be successful in life, 4) improves students' oral and written language skills, and 5) exposes students to careers in the science field.

Urban Engineers—Geotechnics Relationship in a Graduate Curriculum.

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For twenty years beginning the 1950s, Brazil underwent an intense and fast urbanization process. Industrial growth and rural modernization affected the cities' urban quality to the point of challenging urban planners and managers for their chaotic outcome. As for Brazil's undergraduate courses, the teaching of geology (for instance) is hardly focused, so that engineers and architects are not provided with the necessary knowledge about environmental attributes.

The Federal University of Sao Carlos' Urban Engineering Graduate Program intends to produce professionals from a different approach. It seeks to develop in them an integrated view of urban infrastructure with urbanistic patterns and housing, which involves the working together of problems and solutions of different nature according to a terrestrial perspective. Focus is given to medium and small size towns, while the targeted public are civil engineers, architects, surveyors, geographers, cartographers and geologists who intend to approach the city problems and planning processes from a multidisciplinary view.

The Program's course called "Geotechnical Survey in Urban Sites" refers to the most frequent geotechnical problems in Brazilian towns, concepts of geology, pedology, and geotechnics applied to geology engineering, as well as the main methods of underground survey. These aspects are given as a required feature within the Program's range of courses.

Topics such as erosive process, slope stability, building and road foundation, choice of waste disposal area, and underground aquifers are discussed as their understanding contributes to the search for attributes that identify demands and ways of approaching them in urban planning and projecting.

After three years teaching this course, we have come through fine course works oriented towards urban intervention that considers this site's geotechnical characteristics. Course works have therefore assessed their problem by making use of technical terms common to the various professional areas related, as much as perception and high-quality information about the environment within which the town is located. By doing so, the students are stimulated to work out ways of improving the town's quality and reducing the effects of the bad site occupation.

Enlargement Proposal of the Program for Geology in Elementary and High Schools in Brazil.

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Lately, there has been much discussion about the preservation and protection of nature and the environment by the media and schools themselves. Many areas were reserved for parks, recreation, botanical gardens, and zoos, in an attempt to get humans in contact with nature and preserve natural resources, mainly the unreplaceable ones.

However, regarding the programs of Elementary and High schools, little emphasis has been given to Geology teaching, being only considered in College and undergraduate programs. Therefore due to the general ignorance of the planet's geology, there has been a continuous destruction of rock formations which are beautiful and very important for the elucidation of the History of the Earth. Moreover, they could even be used as sightseeing and recreation areas as well as field study areas, since they are real natural museums. Based on this, we can observe a lack of connection between what is taught at school and real life in the society, related not only to Geology but also to other matters.

A programmed Ecology course is proposed for elementary and high schools, because it not only serves as a base for many other Sciences, but also leads to a better interaction among them, such as Ecology, Biogeography, Limnology, Pedology, etc.

The Geology program which is being proposed aims to reach the Brazilian population through elementary and high school teachers and students, developing activities such as: integration between the Brazilian university and the schools, through the Extension and Especialization courses; official implantation of geological content in the School Science Programs, including in them excursion programs and field classes for the students, in order to recover the interest, value, and respect to geological formation, mineral and fossiferous deposits and archeological sites, creation and organization of Geological Science Museums in towns as well as schools, always counting on the students' cooperation, in order to make them interested in knowing rocks, minerals and fossils, and their importance to human beings; organization of an audio-visual library with maps, videos and transparencies as well as elaboration of geological show room projects.

Geoscience Education in Schools: Experiences of an Indian Teacher.

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Geosciences is not a separate course of study in most Indian schools. Geoscience-related topics are taught by Geography/Social Studies teachers who do not have any formal training in these topics. The student comes to know of Geology as an independent optional subject and of the possibility of pursuing a career in Geosciences only when he enters the portals of a college. Because of these reasons, the discipline of geosciences loses many bright students.

Due to parental and peer group pressure, young students take to engineering, medicine and other professional courses. The number of students opting for science, let alone geology, is dwindling at an alarming rate. I believe, this trend is prevalent in both the developing and the developed nations alike.

If this trend continues, the day may not be too far off when geosciences would lose their importance in the eyes of the society and be relegated to the background. In order to avert such a disaster, all people connected with geosciences must act now. They must take the initiative to embark upon a series of programs and activities aimed at creating interest among children in geosciences, informing them that they can pursue geoscience careers in an array of fields, helping school teachers to teach the subject of geology better and also educating and creating awareness among the general public. The last aspect is supremely important because unless societal attitude towards geosciences changes, support for geosciences and its practitioners may not be forthcoming. This paper summarizes the experiences of the author in organizing a few programs meant for school children, school teachers and the common man.

For school children

A few colleagues and I visited schools to deliver lectures (illustrated with slides) on topics that kindled interest in the young minds. A mini-exhibition of samples of rocks, minerals, ores and fossils with catchy slogans and posters was organized.

For school teachers

"Geology Orientation Courses" were organized for the benefit of school teachers who teach earth science-related topics. In the initial courses, a series of lectures on geoscience topics was arranged. Although the participants found the course useful, they felt that it was a tightly packed program. Subsequently, the course was redesigned to consist of only two lectures (one on the role of geosciences in our day-to-day lives and the other on the rocks and minerals of Karnataka State). Plenty of time was allowed for discussion and question-answer sessions. Teachers came up with their own doubts and queries and those raised by their students in the classroom. A video film (audio-dubbed in Kannada language) titled *Volcanic Island* was screened. It gave a good idea of volcanic activity, volcanic landforms etc. and of how people live in such areas. (In fact, on returning to their home institutions, some teachers requested me to play the video tape for their school children, which I did. Being a graduate teacher, it was an interesting experience for me to see the children watch the film in rapt attention.)

The participating teachers spent time at the departmental museum examining and studying different types of rocks, minerals, etc. This was a particularly exciting experience for them. At the end of the program, a certificate of participation and a boxed, labeled set of samples of rocks, minerals, ores and fossils that are referred to in the school curriculum were presented to every participant. Course notes were also provided.

FOR COMMON MAN

Stalls were put up at exhibitions in Mangalore city. Again, samples with catchy slogans, poster materials and various oceanographic sampling instruments were on display. The stalls were visited by several thousand people, including school children.

A Geology quiz was conducted on the All India Radio, Mangalore, for college students who did not have any formal training in geology. Winners of the quiz contest were awarded prizes. Geoscience was also popularized through talks (with colorful slides) delivered at service organizations like Rotary club and on the All India Radio and also through newspaper articles.

CONCLUSIONS

Invariably, all these activities were successful and were found useful by the participants/audience. If the necessary spark is provided to children in their formative years, geosciences can draw enthusiastic students into its fold. Common man can also be made aware of the pivotal role played by geosciences.

Unusual Problem in Education Reforms.

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After the USSR disintegration, the new states faced the problem of a new educational strategy choice. In spite of all the differences, there is a certain similarity in the content of the reforms: the compulsory education period decrease; the private and other types of education permission at all levels; the educational fees gradual introduction; abolishment of the high school graduates allotment.

While generally reforming education, it is necessary to create the programs that will survive various reforms. The most pressing issue is raising the educational standards at all levels.

At the background of the continuous changes, the role of the earth science integrative course is strengthening. Without replacing traditionally strong high and higher school subjects such as physics, chemistry, biology, the earth science focuses on the core of all subjects—the planet Earth, defining cause-result relationships of the nature processes in time and space.

Eschwege Geology Center and the Espinhaço Mountains: The Institution and a Field Geology Laboratory in Central Plateau of Brazil.

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Eschwege Geology Center (EGC): The EGC was founded in Brazil's Diamantina town as an independent institute in 1970 by the German geologist Reinhard Plfug, to honor the eminent geologist W.L. von Eschwege, who made the first studies of the Espinhaço's geology at the beginning of the 19th century. By the end of 70s the institute was incorporated to the Federal University of Minas Gerais at Belo Horizonte. To support the courses, the EGC has available computers, petrographic and aerial-photograph labs, conference and class rooms, a reasonable geoscience library and a small geologic museum.

Location: Diamantina town exhibits a splendid and well preserved baroque style architecture of 18th century. The region has an average temperature of about 25°C in the summer (December to February) and 13°C in the winter (June to September). The annual rainfall is about 500 inches, mainly during the summertime.

Courses and Students: There are in Brazil 19 undergraduate courses of geology, and 18 are state universities. All of them send their students during vacation for a traditional two-week field-geology course at EGC. The students are generally in the final steps of the courses at their universities. Actually the EGC receives about 150 students/year and all the costs related to the course are provided by the Brazilian government. There is also an extended 12 month field-geology course for training graduated geologists. Besides the geological aspects, the EGC supports studies of the physical and agrarian geography, botany and archaeology of the Espinhaço region. The center is also utilized to host congresses and conferences.

Methodology: The traditional two week-course involves groups of 2 or 3 students making a geological map of a previously selected area of about 10 square miles, according to the interest of the students (predominance of tectonic or sedimentary aspects, etc). Before the mapping there are the following steps: (i) a bibliographical research about the geology of the Espinhaço Mountains in the EGC's library, (ii) aerial photographic interpretation of the study area, (iii) a regional two day fieldtrip, including all the students and teachers. In the specific work phase, the students map the area using aerial photographs (scale=1:25,000), make geological profiles, collect samples for thin-sections, and so on. There is a professor-advisor for every 3 or 4 groups. At night each group and its advisor have a meeting to discuss general questions about the final presentation. At the end of the course each group gives a public presentation of the geological map in the auditorium for all the colleagues and teachers. (Unfortunately the advisor is also responsible for the results!) The final evaluation results are sent to the students' universities.

Geological Setting: In the southern Espinhaço Mountains an Archean basement and supracrustal rocks are overlain by low-grade metamorphic Proterozoic rocks of the Espinhaço Supergroup, formed mainly by conglomerates and breccias (diamantiferours), quartzites, dolomites and phyllites showing 15.000 feet of maximum thickness. There are marine, fluvial, eolian and debris-flow depositional environments, showing several kinds of sedimentary and tectonic structures. Facies developed in the lower portion of this Group indicates formation in a simple shear rift basin. An initial deformation phase created a large system of open folds associated with regional uplift, glaciation and basic magmatism. A second deformation phase of collisional thrust tectonics has formed a pile of nappes which was thrusted onto a subsiding foreland basin. The rocks are generally covered by a savanna-type vegetation and occasional drainage forests.

Session Summary: K–12 Programs

Summary was written by Vic Mayer from notes submitted by the discussion leaders: Mayer, Norikazu Osumi, and Judith Riestra.

A variety of issues emerged from among the three discussion groups, ranging from the nature of the science taught being influenced by hot and cold wars over the past century, to specific programs in preparing precollege teachers, to problems experienced by teachers seeking to implement new courses or teaching methods and materials in their schools.

The influence of the "New Right" seems to be world wide. These groups have been successful in causing the restructuring and reduction of funding for schools in Australia and New Zealand, downsizing of instructional staffs in many developed countries, criticisms of teachers for teaching about evolution and the age of the Earth in many countries, and outright revisions of curricula in very conservative local areas to give credence to "scientific creationism." The influence of the "New Right" seems to be growing in strength and must be of major concern to those who teach about our Earth at all levels.

Often when Earth science is added to the curriculum of a nation such as the Philippines, it is taught by individuals trained in one of the other sciences. In fact, this often occurs in other countries where the demand for Earth science teachers is frequently in excess of the supply. Someone trained in biology or some other science will be asked to teach Earth science. Where school systems are downsizing, it often occurs that there is an oversupply of teachers in the school system in some areas of curriculum and a scarcity of teachers in others such as in Earth science. Often these vacancies in the Earth sciences will be filled from the pool of excess teachers from other curriculum areas. The question then arises, are there special skills and knowledge needed by the teacher of Earth science that are not developed in other areas of science or other areas of curriculum? If so, then special programs are needed for the preparation of effective Earth science teachers. If not, then simply providing reading materials may be sufficient to prepare these new teachers of Earth science.

There is a world-wide need for a much stronger Earth science curriculum in elementary school. The subject is especially adaptable for teaching basic skills in reading, writing and math, as well as for establishing the basis for the development of knowledge regarding how the natural world works. Earth science can also capture the interest and imagination of young children.

Pre-college teachers lack sufficient training in Earth science content and methods. A variety of local, state (provincial or prefectural), and national agencies must be involved in improving Earth science teacher competencies. The Korean Ministry of Education, for example, has provided support for Earth science teachers to participate in especially designed programs in several different countries including Great Britain and the USA over the past decade or so. To be most effective, such programs must work with a small group of teachers, providing them laboratory and field experiences, visits to working schools, and research experiences in Earth science.

Resources devoted to educational reform must go primarily to teachers to assist them in attending specially designed courses, improving their salaries and social position, and providing them with adequate facilities, resources, and equipment.

The knowledge and background of teacher trainers must be improved. They need to be involved in educational research and teaching materials development, use the latest technology, participate in pre-college instruction, and serve with scientists on college and university programs.

Theme II: Earth Systems/Science Instruction and Learning

E. Barbara Klemm and Nir T. Orion, Coordinators

Session IIA: Using Technology for Learning at the College and University Level

Ian Clark and Edwin L. Shay, Moderators

Presentations in this session highlighted the wide range of technological tools for learning and teaching Earth systems science. From simple e-mail and video for remote areas, to national courses on the internet, methods of connectivity were explored. New tools such as GIS, CD-ROMs, virtual reality and data visualization were demonstrated as means of making information relevant, establishing interdisciplinary connections, and providing data access for problem based learning. While such technologies have been used as science tools for some years, their application in education is just developing, offering exciting and creative means of learning about the Earth as a system.

Supporting Critical Thinking Using Technology in the Large General Education Oceanography Class.

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The "Our Dynamic Planet" CD-ROM has been created to support student activities that access real data about the earth, encourage thought about its meaning, foster discussion about it with their peers, and write about their findings. In order to eliminate as much administrative work as possible, the system allows the students to enter homework answers for automatic grading, take "mastery quizzes," and review their grades. Writing is done within the software environment which allows electronic "hand in" to their teaching assistant or random anonymous distribution for peer review and return. "Store and Forward" is implemented so students can create a key disc (floppy) that will allow them to work at another computer (not connected to an AppleTalk network), yet still get credit for their work.

The software consists of two modules. The "Class Master" module provides tools that are common to most courses. It contains the log-in, writing, grade analysis and "store and forward" capabilities. It also links to content modules through setup files that may be customized by the professor. Templates are provided so that the professor can create his/her own modules that can be seamlessly incorporated into the system. Student activities are logged automatically to a "mailbox" file on a Macintosh server.

The main content module consists of earth elevation, volcano, earthquake hypocenter, seafloor and island ages, heat flow, movies, and still graphics. With these data, students can study plate boundaries and find evidence for the theory of plate tectonics. Other modules include homework, a geography game, a profile game, and other intonation about volcanoes and the earth.

This material has been used in the UCSB Oceanography course, which has an enrollment of about 250 students, since 1995 and has received excellent student feedback. The use of this software has been coupled with a significant increase in student workload and quantitative content. A term paper substitutes for the usual midterm quiz, homeworks are required and must be entered on time, and students are accountable for all of their work. Student acceptance has been high. They appreciate the increased clarity of expectations regarding their performance, increased feedback on their performance, and increased support with the difficult material.

Information about this work may he obtained at *http://oceanography.geol.ucsb.edu/courseware/index.html*

Integrating GIS and Digital Maps into the Curriculum at a Small College.

Russell G. Clark, Jr., and Timothy N. Lincoln, Department of Geological Sciences, Albion College, Albion, MI, 49224 USA.

Images, including maps, are central to earth science education and research. Increasingly, these images are being created, stored, analyzed and displayed in computer-usable digital formats. Geographic Information Systems (GIS) are computer systems that facilitate the display and analysis of spatial data...any kind of data whether they be geological (e.g., the distribution of rocks, natural resources, or earthquakes) or non-geological (e.g., the distribution of hospitals, transportation routes, or voting patterns). In the past the academic use and development of GIS has been largely restricted to geography departments, but like many other small schools, Albion College does not have a geography department. Today, the use of GIS has advanced across disciplinary boundaries to the point where most students (especially, but not limited to, earth science students) should be aware that GIS exists and should be able to explore its use at least at an elementary level.

At Albion College the Geological Sciences department has taken on the role of introducing GIS to earth science and other students by establishing a GIS and Digital Map Laboratory. This lab has been funded in part through an NSF-ILI grant for the purchase of appropriate computer hardware and software.

The project involves curricular changes at all levels: (1) the development of two courses (one introductory, one advanced) on GIS and digital maps; (2) an introduction to digital mapping during our summer field geology program in the Rocky Mountains; and (3) the revision of mapping exercises and projects in as many as nine existing geology courses. The largest number of students affected by this project is in our Introductory Geology course (~50 students per semester), where students use an elementary GIS package (ArcView) to study relationships between the spatial attributes of a topic of their choice.

The lab consists of a local network of nine Pentium-based PC workstations, plus a Windows NT server, and a Silicon Graphics Unix workstation. A 18" x 12" digitizing tablet is attached to each computer and there is also a 36" x 24" digitizing table in the lab. Other peripherals include a color flatbed scanner, a transparency scanner, a color B-size plotter, two color inkjet printers, two laser printers, and an E-size color printer/ plotter. In addition, the local network is connected to the larger college-wide network and to the Internet. GIS-related software available in the lab includes ArcView GIS (PC and Unix), ARC/INFO (PC and Unix), ArcCAD, and ER Mapper (PC and Unix). Numerous digital images (e.g., satellite images and orthophoto quads), scanned digital maps, DEM, DRG, and DLG files, as well as other digital data sets are available for student use.

Establishing the GIS and Digital Map Lab in our department required solving (or at considering) many problems. These problems included: (1) locating sources of funding with which to purchase over $100K in equipment, software, and digital data; (2) finding space for the lab within a department that was already short on space; (3) developing the necessary expertise to teach the relevant courses; (4) developing (or finding someone with) the expertise to install and maintain the hardware, software, and local network components; and (5) finding the time to accomplish all of the above.

A Graduate Level Course in Earth Systems Science for Middle School Teachers.

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Under the sponsorship of the National Aeronautics and Space Administration's Mission to Planet Earth, the NASA Classroom of the Future, Wheeling Jesuit University, has developed a graduate level course featuring Earth Systems instruction. The course is delivered in 16 one-week segments through a Website on the Internet.

Participating teachers are led progressively through the concept of Earth's interacting and interdependent spheres which are driven in large part by solar energy. They then proceed to system and subsystem analysis, examination of inputs and outputs, feedback loops, positive and negative feedbacks and dynamic equilibrium. Finally, the teachers consider interactions among the spheres as a result of various feedbacks as well as delays in response due to inertia in the system or subsystems.

Participants are shown by example how to develop 'situations' based on local or well publicized regional events for students' classroom analysis. Emphasis is on helping young people see potential impacts of the selected event on Earth's spheres and the subsequent feedback and potential interactions that might result. Rather than emphasize a "right or wrong" answer, the student should be able to explain why he or she suspects such an anticipated result is a reasonable expectation.

Other materials are presented in the Internet course within the context of Problem Based Learning. Each section of 20 teachers is moderated by a master teacher and an Earth System scientist. Weekly reflection on the content and pedagogy as well as the implications for classroom application is required through the use of a participant journal.

The course was pilot tested on-line starting in mid-January, 1996, after which a re-evaluation of sequence, process and materials was completed. In the future, the revised course is intended to be administered by members of the Space Grant Consortia.

The Pacific Rainfall Climate Experiment: Using Technology to Study the Earth System.

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The Schools of the Pacific Rainfall Climate Experiment (SPaRCE) is a cooperative educational and research project that involves elementary, middle, and high schools, trade schools, colleges, and meteorological services from various Pacific islands, atolls, and the U.S. The educational materials that the program provides to Pacific area schools primarily involves the use of non-technical, simple equipment and experiments. These include plastic direct-read rain gauges, and workbooks and videos that discuss tropical Pacific related phenomena. The lack of more technical, computer-based curricula is due in part because many schools involved in the program are located on isolated islands or atolls where supplies are sparse and quite expensive. Many schools do not even have the use of electricity.

In collaboration with the Department of Energy's Tropical Western Pacific Atmospheric Radiation Measurement program the SPaRCE program was able to successfully deploy 3 prototype automated weather stations in the summer of 1995. These stations were set up at schools that were located in more urban areas of the Cook Islands, Vanuatu, and Papua New Guinea. In the summer of 1996, SPaRCE was able to set up 4 solar-powered automated weather stations in Western Samoa, Tonga, and Pohnpei. The presence of the automated stations (which include a laptop computer) in addition to the standard direct-read equipment is an excellent way for Pacific area students to become more familiar and comfortable with using technological equipment. This is also a useful way to teach students about scientific basics such as quality control and instrument comparisons. The SPaRCE program has also supplied four Pacific-area schools with MicroTops—a hand-held radiometer which measures total column ozone.

The rainfall and other data collected by the students are used by climatologists around the world. The SPaRCE program allows students to learn science in the context of participating in a real scientific study. Most importantly, it exposes students to technology and science education that many of them might not otherwise receive due to the isolation of their schools.

Remote Sensing and Multispectral Imaging of Vegetation at Biosphere 2.

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Remote sensing and multispectral imaging techniques are important in the measurement and monitoring of global vegetation. We are undertaking an undergraduate research project which involves using these techniques in Biosphere 2, Oracle, AZ, a facility with seven earth modeled biomes. The project is a cooperative venture involving Columbia/Biosphere 2 and the University of Arizona/NASA Space Grant Undergraduate Research Internship Program, and provides the opportunity for student/faculty research utilizing earth system related technology and non lecture based learning environments to further public awareness of remote sensing and multispectral image processing techniques.

The Biosphere 2 facility is a unique outlet for remote sensing experimentation as it contains numerous biomes modeling those on earth. Access to hundreds of diverse plant species, control of environmental conditions (soil moisture, rain, temperature, increased CO2, nutrients) and extensive plant physiological characterization provide a unique arena for remote sensing studies. Manipulation of the environmental conditions, along with a remote sensing based monitoring system can be effective in determining plant response to variable conditions. In the summer of 1996, 260 images were taken in 4 biomes (desert, rainforest, upper thornscrub, lower thornscrub) with a Kodak DCS 420 IR digital camera. Narrowband transmission filters were used and filter passbands ranging from 0.4 to 0.95 m were selected that complemented plant reflectance. These tools produced digital images available for analyses, including classification of plant species within the biomes, using image processing software.

Goals of the project include demonstrating digital imaging as a technique for monitoring changes in vegetation inside Biosphere, and illustrating the methods and application of remote sensing for education. We will make efforts to educate the public by making our methods, analyses, and results, including images and descriptive text, available on the University of Arizona Space Grant/Biosphere 2 web page at *http://pirl.lpl.arizona.edu/biosphere*. We believe the world wide web can serve as a non lecture based learning environment and is a form of outreach education for our earth system related research. Accordingly, we intend to use the web as a forum where interested parties are encouraged to make comments, suggestions and ask questions about this research by email directly from the page. Recently, there has been much publicity surrounding the topics of global and climatic change, ecosystem studies, and especially the effect of CO_2 levels.rising and the impact on vegetation. The discovery of which techniques of data collection and analysis, including digital imaging, are best suited for Biosphere 2, will be useful information for efforts to monitor plant physiology and ecosystem response to environmental parameters of concern to global change. We believe this information is important not only to the scientific community, but to the community at large. As such, we are eager to spur interest and facilitate an educational environment based on our findings.

Actual Earth, Virtual Earth: Two Approaches to Constructivist Learning.

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In 1996 I created two new Earth systems classes at Everett Community College, a field-based class and an internet-based class. These curricula may sound diametrically opposed, but both are based on the idea that the best way to learn about Earth systems is to go beyond textbooks and engage the world as directly as possible.

In March of 1996 I co-led a class from Everett Community College that spent a week on Hawai'i, studying the geological history of active and dormant volcanoes; the flora and fauna of a remote oceanic island; ecological adaptations to lava flows ranging in age from less than a year to thousands of years; and the decimation of endemic species by introduced species and habitat destruction. The main goal of the class was to develop an experience-based conceptual understanding of the dynamics and interrelations of the Earth systems. Daily learning exercises were built around field journals that were turned in each night for instructor feedback, and which provided students with source material for the summary papers due at the end of the course.

The results of these learning methods suggest a number of pedagogical lessons. For instance, on the one hand some students floundered to find answers in the absence of textbooks, but on the other hand that made it clear they needed experience solving problems in the real world. Judging by the quality of student work, the comments and the course reviews from students, and the richness of the Hawai'i experience itself, the main goal was satisfactorily achieved. Hawai'i is a spectacular natural laboratory for observing and experiencing interrelated Earth system processes as they happen. Students who take such a class may find that they cannot think of geology, ecology, climate, and culture as separate categories again, as long as their Hawai'ian memories are conjured by the words Pele, pu'u, paho'eho'e, ohi'a, and nene. Such learning cannot be achieved in the classroom, but it offers lessons that can inform and enrich classroom curricula.

In sharp contrast to an in-person excursion to Hawai'i is a virtual trip taken through the world wide web. Everett Community College has provided grant money to design and implement an Internetbased Earth systems curriculum, to be taught this Spring. The learning assignments I am creating are meant to take advantage of the Internet for constructivist learning. One of the challenges will be to have the students understand that the web is a place to get information, not knowledge, and that the information itself is not impeccable. The knowledge doesn't come until the student evaluates and processes the information, weaving it through their own efforts into a conceptual model that holds up to reason, explains the observations, and makes predictions. I reported on how well the Internet worked as a medium for constructivist learning in an Earth systems class.

Adapting Freshman Level Geology Courses for Distance Learning.

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Distance learning is becoming an increasingly popular option, particularly at multicampus institutions, or where student demand for courses exceeds faculty availability. At DeKalb College in the Atlanta, Georgia area, we have combined three technologies to develop a effective distance learning course sequence in Geology: the World Wide Web, compressed video over telephone lines, and e-mail.

Students access the World Wide Web for syllabus, course notes, and assignments. On line lecture notes are projected in class from a multimedia computer with ethernet connectivity. Lecture notes include graphics such as line drawings and photos of laboratory specimens, field localities, and museum exhibits. Students print out the web notes before class and bring them to lecture. The web site is located at *http://www.dc.peachnet.edu/~pgore/gore.htm*. Notes on the Web help non-native speakers of English, disabled students, and "at risk" students. They are particularly useful in the distance learning setting. Computer based assignments direct students to outside web sites where they read and answer questions, gather data for interpretation, view satellite images, take virtual field trips, and research current Earth System events such as earthquakes and erupting volcanoes. The global perspective provided by satellites and the capability for rapid worldwide data transmission via the Internet allows students to use real time data on the ozone hole, sea surface temperatures, floods, and climatology. As a final project, students working individually or in groups prepare multimedia research projects written in hypertext markup language, which they submit on disk.

The distance learning component of the class is transmitted over the Georgia Statewide Academic and Medical System (GSAMS). GSAMS is an interactive distance learning network connecting more than 350 sites statewide in K–12 public schools, colleges, universities, technical institutes, hospitals, prisons, and other sites including ZooAtlanta and Georgia Public Television. It sends compressed video signals over T 1 telephone lines. Using GSAMS, people in up to eight locations can see and speak with one another. Distance learning is particularly helpful in teaching Geology at DeKalb College. DeKalb College is a multicampus institution with five locations, but full time geology faculty staff only two of the campuses. Using GSAMS, we are offering two sections of freshman geology simultaneously on different campuses, with one instructor alternating between sites (there are about 24 students in each section). This allows us to reach students in the under served locations. Laboratory classes are held on the day the instructor is on site. Electronic mail is used to announce assignments and to communicate with students outside of class. This allows them to ask questions and resolve problems easily although they see the instructor in person only once each week.

Using GIS in non-GIS Geoscience Courses at IG-USP—Brazil.

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Geographic Information Systems are used as learning tools in Geoscience courses at the Institute of Geosciences of the University of Sao Paulo, Brazil, since 1992. There are specific courses on GIS and Remote Sensing at the Institute, and GIS activities are used in non-GIS courses, objects of this paper.

The first uses of GIS were demonstrations in Environmental Geology and Planning Geology courses, since 1992, using applications for environmental impact assessment and urban planning projects, such as flood and landslide prevention, urban development and construction materials assessment. Since 1993 GIS activities were incorporated to the "Mining and the Environment" course, which is intended to give training in the fields of EIA/EIS for mining projects and reclamation of land disturbed by mining. Groups of students (two to four each) developed GIS on active and abandoned mining areas, to support EIA and reclamation projects. The students had no previous GIS training, and were taught short IDRISI and TOSCA tutorials. Undergraduate student assistants and the teacher were available for support. The databases consisted in map layers with geology, vegetation, disturbed lands, drainage, contour lines, pollution sources and mining activities, and files of geochemical and mineral production data. Contour data were used to interpolate digital elevation models (DEMs), used as basemaps for displaying and studying other layers.

In 1994 GIS methods were used together with traditional photo-interpretation in the Aerophotogeology course, for a project developed in connection with technical assistance to the government of the city of Bomsucesso de Itarare, one of the newest and poorest municipalities of the State of Sao Paulo. A DEM together with geologic and geomorphologic maps were used as tools for a planning project developed by undergraduate students.

Although these experiences were not technically evaluated, some results can be perceived: 1) there is an increase in interest and participation from the students, when GIS methods are used, in comparison with traditional methods; 2) there is an improvement in quality of the projects using GIS. These systems allow the students to combine spatial thinking, traditional to geologists, with database exploration, resulting in a greater understanding of the problems. Mitigation and reclamation measures can be simulated in 3D models, allowing the students to see the results in a better way than 2D maps; 3) the programs used (IDRISI and TOSCA) were considered adequate to the function. They have analysis capabilities needed for the projects and are easy to use, allowing the students to build and manipulate GIS with short training and little support.

The Achievements of the European Space Agency Using the Meteosat Image Data.

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The European Space Agency (ESA) has, by its convention, the mandate to undertake European level research, development and demonstration of Earth Observation related space technologies. The widening of knowledge and the stimulation of the use of Earth Observation data and information require, inter alia, measures to ease access to Earth Observation information.

In the frame of the Meteosat Operational Programme (Operations of the Meteosat series of European Meteorological Geostationary Satellites from 1981 to 1995), the European Space Agency has provided the users communities with Earth Observation data extracted from its Meteosat archive. The Meteosat images consist of a new scanning of the full earth disk every half hour in each of three spectral channels: .5–0.9 m (visible light band, 2.5 km resolution), 5.7–7.1 m (infrared water vapour absorption band, 5 km resolution), 10.5 12.5 m (thermal infrared window band, 5 km resolution).

In view of making these images available to the largest possible users community ESA decided in 1992 to use the maturing CD-ROM technology for publishing coherent sets of Meteosat data usable on any PC. Four CDs have been published from 1993 to 1995, the last two containing full resolution data of selected areas of the globe. The feed-back from the users of these CDs can be can be summarized as: great content, poor user interface. Therefore ESA has produced a fifth CD-ROM called "the weather machine" featuring a new, attractive, highly interactive user interface. It contains the Meteosat data for eighteen classical weather situations in a format compatible with the 3rd CD ("weather in motion") which can also be accessed through this new interface. Scientific and meteorological descriptions of the situations, in text and graphic forms, make the CD ideally suited for classrooms teaching. The user can at will merge two spectral channels, superimpose geographical grids and coast lines, watch the AVI loops included, export the images with or without date stamp for inclusion in his documents or for production of his own loops. The calibration data provided allow to convert the radiometric counts into temperature.

Thanks to the implementation of a hard-disk updatable database the user is encouraged to complement with his own text and graphics material the texts and graphics included on the CD. A specially designed Meteorological Graphics Tool Box allows him to draw on a graphical layer on top of the images and to store his drawings on disk. He can then at a later stage, typically in the classroom, recall his drawings as well as the graphics originally delivered with the CD-ROM. The interactive interface as well as all text data are provided in English, French and German.

Concept Mapping and Computer-Aided Delivery in Advanced Structural Geology.

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In our experience the teaching of structural geology has not been as effective as it should have been. Assessment results indicate that only a small group of students is successful in developing an understanding of the higher order concepts and how they are related one to another. The majority of students are able to complete the unit by rote learning but do not carry the knowledge as well as we would like into subsequent units.

During the past four years the teaching approach that we have used has been modified from a traditional one using lectures and practicals to introduce new information, and fieldwork to apply the newly acquired skills, to a more integrated and interactive approach. Lectures have become less formal encouraging student participation, direct delivery hardware to project computer generated images is used instead of normal overhead, video, and 35mm transparencies and students are taught to construct concept maps.

We felt that teaching students to construct concept maps would help them recognise the major concepts and the links between them which would lead to more meaningful learning and less rote learning which in turn would promote better application of concepts and skills. Analysis of exam results, comparison with previous results and comparison of achievement in similar courses has shown a significant improvement in student achievement. Evaluation of student attitudes using reflective journals has also reinforced the impression that the modified approach has been worthwhile.

Earth Systems Science and Global Change Issues as Taught in a "Traditional" Historical Geology Course.

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A post-secondary geology course was re-designed to attain several goals. First, the course was designed to assist non-science majors in learning that the earth has a history that is not just geological but also multifaceted. The earth was to be examined as a system of interrelated components: biosphere, geosphere, hydrosphere, atmosphere, cryosphere and biogeochemical cycles. The second goal of the course was to inculcate students with the knowledge base from which they could make informed decisions regarding global change issues. This latter goal was based on the belief that scientists have a duty to educate the general public, in this case post-secondary non-science majors, to assist them in becoming more scientifically literate, particularly with the important issues of global change.

The course that was redesigned was an historical geology course, typically offered at most geology departments. Historical geology appeared to be a perfect avenue with which to explore earth system science in terms of past and future global change processes. The topics covered in the course by no means offer an in-depth examination of the issues of global change but do raise the level of understanding of the issues for non-science majors.

Teaching methodologies consist of lectures, cooperative learning groups (including exercises based on the Jigsaw Classroom by Aronson, 1978), outside reading assignments, class discussions, videos, and exercises drawn from "Education for Global Change" produced by the International Council of Scientific Unions. By utilizing several teaching strategies it was hoped that the students would have a keen level of interest in the subject matter. Historical geology is also a laboratory course which entails meeting weekly for two-hour lab sessions. This component of the course provided for a combination of common historical geology exercises along with global change exercises, some of which were derived from: "Education for Global Change." Students also spent two computer laboratory sessions using "SimEarth: The Living Planet," a software package of MAXIS. This software package allows students to manipulate earth systems as they evolve throughout geologic time.

The course sequence allows students to develop an understanding of the physical characteristics of the earth. Once this is mastered students begin to explore how the earth's systems are connected and how feedback mechanisms play an important role in the evolution of those systems. The earth system science sequence is concluded by examining the tools and methodologies used by paleoclimatologists, paleoceanographers, and paleoecologists. Armed with this knowledge base, the final project requires students to make oral presentations regarding the probability of the threat of global warming. The interactive poster session will present examples of course materials and exercises as well as student feedback.

Session Summary IIA: Using Technology for Learning at the College and University Level

This summary was written by E. Barbara Klemm from notes provided by discussion leaders Ian Clark, Edwin L. Shay, and herself.

Eleven interactive posters in this session explored research related to earth system science course restructuring that incorporates innovative use of instructional technology. Several posters described how computer and satellite tools developed for scientists were adapted by educators for constructivist approaches to teaching and learning. Presenters reported on use of digital data accessed from CD-ROMS, GIS and other databases to design, deliver and manage authentic, problems-based learning opportunities. Issues included ways to assist learners in visualizing and interpreting data, in connecting global or regional views with locally-situated data, and in grounding virtual reality with real-world experiential learning.

After the poster session, break-out sessions discussed innovations in instructional technologies, emerging trends, and concerns which they called "the dark side of the web." Overall, consensus was that relevant information is now available through a variety of instructional technologies that pose new possibilities—and problems—for teaching and learning. A key aim is to introduce various technologies into the classroom so that students can use the same tools that researchers are using. Others are to teach better and to better facilitate student learning.

The internet seems to be a valuable tool, but is not available to everyone, even in developed countries. Scientists tools are more sophisticated and expensive than educators', particularly in technical power for visualization of data. Instructional computer monitors, for example, may have fewer lines of resolution or pixels than required in scientifically- rendered, detailed virtual images. Discussants expressed frustration in not having ready access to real-time data, but acknowledged that the scientists' priority is to generate research results, not to produce educationally-accessible data.

Data providers and educators need to communicate so that the information which is available is useful for teaching and learning. Inexpensive yet valuable learning experiences are now available to educators, e.g. using GIS and commercially developed instructional packages. Concern was expressed about cost for access to data sets generated through public funds and about commercialization on the internet.

Too much information may now be available through the web, and the information surfeit is confusing students. Much of the information has not been validated through scientific peer review. Information rapidly appears, is disseminated, and often disappears quickly on the web. New educational challenges are to teach skills related to information searching and retrieval and to teach critical selection and use of information. Especially important is the ability to discern ideological or commercial bias.

College and university instructors in the group also voiced concern that cost-cutting, revenue generating measures introduce instructional technologies to increase the size of classes. Some expressed concern over visions of virtual universities in which a few super-star professors teach on the web to large numbers of geographically dispersed students, thereby emphasizing quantity rather than instructional quality. From experience, instructional technology users reported spending more time in contact with students, and less time devoted to research. In particular, they cited the time required for email responses, for inputting and upkeeping their computerized instructional delivery systems.

Session IIB: Teaching at the College and University Level

Donald L. Oakley and Michael Walsh, Moderators

Papers in this session focused on alternative methods of instruction in higher education: teaching about interactions, developing writing skills, using constructivist methods with very large class sizes. In some cases they worked specifically to increase the science literacy of non-majors, with national parks, newspapers, local examples, and creative sequencing of topics. Their classes took on the big problems of pollution and natural disasters, and examining recent but huge anthropogenic impacts in comparison with the impact of longer term natural processes.

Student Field Studies Related to Assessment and Mitigation of Wildfire Impacts.

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Understanding interactions between meteorology, biology, geology, soils and hydrology is essential for assessing wildfire damage as well as for developing and implementing plans to mitigate wildfire impact. From 1992–1997 three separate wildfires burned over 350,000 acres (142,000 hectares) of forest and range lands in the mountainous terrain adjacent to and near Boise, Idaho. Alteration of other Earth processes by these fires has significantly affected both natural and urban environments. These disasters have provided opportunities for students at Boise State University to undertake a variety of studies related to Earth processes and fires; it has also allowed opportunities for student involvement in efforts by city, state and federal agencies to plan and implement responses to wildfires.

Introductory, overview and case study information has been presented to students via assigned readings, classroom lectures and guest speakers. Students have actively participated in public hearings and the ensuing development of fire mitigation measures. Students have also been employed in the installation and maintenance of a wide variety of soil and stream stabilization measures in burned areas. Directed field studies have been done during class field trips, but student independent research projects seem to have been especially productive with regard to learning and enthusiasm. Field projects undertaken over several years by students in two courses (Geomorphology and Field Geology) have focused on various interactive aspects of soil erosion, mass wasting, and stream systems of burned areas as well as evaluating the effectiveness of wildfire mitigation projects.

Exploring the Desert Environment.

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Representatives from education, business and government constantly criticize the writing skills of college students and their ability to communicate. After the writing exercises attempted in English 101 and 102, their writing experiences and newly acquired skills disappear. Through active writing programs such as "Writing Across the Curriculum." students are required to write in classes other than English Composition. The assignments are appropriate to the specific discipline, and are meant to be nonstressful; they are holistically evaluated and peer reviewed. Students gradually improve their confidence to write better papers and ultimately improve their skills. Many faculty resist programs of this type, stating that they don't have time for such classroom activities or to leave the task to the rhetorician. Physical scientists have been critical of these programs because it takes valuable time from laboratory experimentation, computer activities or quantitative exercises; not realizing that poor writing skills are preventing their students from obtaining careers they have been working toward.

Utilizing the "writing across the curriculum" philosophy, a series of writing exercises has been given to students doing field work in geography at the Big Bend National Park. Although the writing environment leaves much to be desired, the amount of subject matter is abundant. Attempting to describe, compare and identify patterns in an environment which is alien to one's own is an exciting task to witness. The Big Bend National Park was selected because its desert environment was so different from Mobile's humid subtropical environment, and when coupled with altitudes in excess of

7,000 feet, a multiplicity of unique settings provide topics for the student to investigate.

The National Parks of the southwest have always been favorite refuges for Americans. The aridity of the landscape coupled with natural processes of weathering and erosion have provided vistas which are exotic to most Americans. The associations are usually very simple. One is able to relate factors of altitude, seasonal and diurnal temperature ranges, continentality and precipitation with relative ease. There are several parks distributed throughout these arid lands, but Big Bend National Park seems to draw the greatest interest from an assortment of physical scientists. All agree that the unique terrain, distinctive biotic communities, and sheer vastness of the landscape provides a wealth of information on which to write.

Symmetry: Its Control on the Natural Formation of All Crystalline Materials.

Wayne C. Isphording, Department of Geology and Geography, University of South Alabama, Mobile, AL 36688 USA.

Fundamental to the study of the Earth Sciences is the study of symmetry. Symmetry is the factor controlling what particular mineral will form under a given set of physicochemical conditions. Hence, it determines the arrangement of the atoms in a sea shell, in a bar of steel, in a sheet of plastic, in the bottom muds of rivers, lakes, and seas, or those minerals forming in the magma chambers of volcanoes or deep with within the earth's crust, mantle, and core. Yet the concept of symmetry is foreign to most students. Little or no emphasis is placed on it in secondary schools and most students enter geology, physics, and chemistry courses with no understanding of this basic, but all controlling concept. Symmetry is the exact repetition in space of a motif about a plane, line, or point. This motif can be a single atom, or a cluster of atoms. Few realize that there are only five symmetry patterns that can undergo exact two dimensional duplication. Hence, all wall paper patterns are controlled by these five symmetries. Similarly, when extended into the 3rd dimension, there are only a restricted number of general patterns that can develop and which regulate the external form of all crystalline solids. These can be assigned to one of six crystal systems and a maximum of 32 point groups. All naturally occurring or man-made crystalline materials (i.e., everything except liquids, tissue, and "glass") will be represented by one of these basic patterns. There are no others possible.

To develop an understanding the principles that control atomic symmetry, students are given exercises that require them to "build" atomic structures using two computer algorithms having exceptional graphics capabilities. The students begin by selecting a chemical compound and then assign conditions (temperature, pressure, etc.) that will control the ultimate symmetry of the resulting crystalline solid. Using this procedure, the program can display the internal structure of molecules, crystals, and polymers. Once the internal structure has been derived, the student uses this information to ascertain the external macro-scale form of the crystal. Building on these concepts, advanced exercises can then be used to provide the student with a clear understanding of what forms specific compounds would exist in far beneath the earth's surface or on distant planets, why certain minerals may serve as sites for organic and inorganic contaminants in natural environments, how defect structures in solids originate and may cause them to fail under directed stresses, just to name a few.

The Geology of Oklahoma Lab Project: A Model for Enhancing the Relevance of Science for Non-Science Majors.

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We are attempting to increase the relevance of science in a large introductory Physical Geology course by redesigning the laboratory section to incorporate a "research-like" project on the Geology of Oklahoma. The underpinning of this approach is the premise that students will be more deeply engaged in learning how science is "done" when actually doing science on problems with which they can identify directly.

Although this project is ongoing, the ultimate goal is to develop labs that consist of a series of interrelated exercises encompassing the geologic history of Oklahoma and related topical issues (natural resources, environmental problems and geological hazards). The redesigned exercises include a variety of datasets to illustrate the process of science in a "research-like" atmosphere. Each exercise will cover several lab periods and center on four main themes: 1) Igneous processes and mineralogy; 2) Quaternary and environmental geology; 3) Sedimentary geology; 4) Structural and petroleum geology. We have chosen these four themes because they encompass a broad band of the spectrum of Physical Geology topics and because we can incorporate datasets for each exercise from the Wichita, Arbuckle and Ouachita Mountains, all of which are in Oklahoma.

Each "molecule" ultimately includes four parts. The first is a problem statement, which introduces the students to the problem they are about to solve. The second is a series of exploration-type activities that form the constructive base for subsequent interpretation. This is followed by analysis and synthesis of an integrated dataset by collaborative student groups. Finally, the students apply the newly developed concepts to explore a more global process such as plate tectonics, climatic change (short and long term) and the hydrologic cycle, for example. We plan to include multimedia technology to introduce the problem-statement presentations to form a series of short multimedia presentations on aspects of Oklahoma geology which will be made available on CD-ROM to regional high school teachers.

We believe the impact of this work will be three-fold: 1) the emphasis on real examples will produce a general populace that is more aware of local geologic and environmental issues; 2) the focus will shift from classifying and identifying to critical thinking and problem-solving in labs; and 3) the exercises will serve as a model that other institutions can adopt after modifying specific datasets to showcase their local and regional geologic problems.

A Multifaceted, Field-Based Approach to Integrative Geoscience Education.

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What is it? It's for educators. It's experiential. It's collaborative. It's field oriented. It's located in rural Appalachia. It's science/technology/society (STS). It's based on 1996 NRC National Science Education Standards. It's all about water and educators crafting resource materials and curriculum from an inquiry-driven perspective.

Lock Haven University is located in north-central Pennsylvania and both its rural location and regional resources play heavily in our effort to experiment with an interesting approach to science education. We are offering a full-immersion learning experience using visits to a broad spectrum of field sites along with ancillary classroom and laboratory work as a framework for curricular/instructional material development. Our primary target population is junior high earth science teachers and general science teachers at secondary levels, especially teachers involved in STS courses.

This applied program has two fundamental components. The first, content, focuses on the details of the natural surface-water and groundwater systems within the context of a geologic framework that comprises both the Ridge & Valley and the Appalachian Plateau physiographic provinces. Students investigate the uses and abuses of water in the past and those dictated by the needs of this region today and tomorrow. Illustrative case studies abound: a small city sitting in the floodplain of a major river has just completed an extensive flood-protection project; a bankrupt chemical plant site is presently undergoing locally contentious Superfund remediation; a limestone valley characterized by classic karst landforms and features is traversed by an interstate highway generating rapidly expanding feeder roads and interchange zones; contiguous uplands, which have been deep and strip mined for generations, continue to supply acid-mine drainage to regional watersheds. The second component, education, focuses on the study of the character and application of inquiry, a skill underutilized in current practice yet strongly advocated by 1996 science education national standards. Participants not only develop curriculum material and visual resources to carry back to their own classrooms, they generate other case studies appropriate to their own courses and their local situations that illustrate similar water-related STS concepts.

Participants in the program—

- study the broader topic of water from a personal and rural/social perspective;
- gain extensive personal field experience with current technology/facilities/ learning sites;
- participate in a fully integrated learning experience with the relationships among basic science, technology, and a host of social, political, and economic factors relating to a selected topic;
- address new NRC *National Science Education Standards* regarding:
  a. teaching science as inquiry (Content Standard A, grades 5–8 and 9–12);
  b. development of ability in technological design and understanding science and technology interfaces (Content Standard E, grades 5–8 and 9–12);
- produce personalized lesson materials for use in classrooms, especially video and photographic materials to support inquiry learning.

The conference presentation characterized the field sites and the lessons to be learned there in addition to describing the methodological approaches used to promote inquiry.

Investigating before Learning Basic Knowledge in an Introductory College Earth Science Course.

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Almost any particular investigative Earth Sciences activity rests on students' existing knowledge base. The more advanced this base of knowledge, the more sophisticated students can be in developing, implementing, and interpreting their own scientific investigations and the closer these investigations can be to actual science. Thus, traditionally, college geology programs present potential majors first with an introductory survey course providing them with the basic knowledge needed to pursue (in later courses) the investigation, inquiry, and analyses that are the substance of science. Such courses are taken by general education students who thus get more thoroughly introduced to the facts we have learned in Earth Science than to the processes by which we have learned those facts. Consequently, science "content" is often mistakenly equated with the learning of basic science facts.

Earth Science Today at Moorhead State is a course intended to introduce general studies students to the "higher thinking" aspects of Earth Science without requiring that they first pass through a traditional introductory course. This course focuses on 5–7 Earth Science topics currently in the news. By reading articles about various topics, students encounter science in much the same way they will encounter it throughout their lives. Because it is "in the news" the material has more apparent relevance to students' lives. By limiting ourselves to 5–7 topics, we have time to develop a knowledge base on these topics, to read and evaluate carefully what is being said in the articles and why it is said. We have time to discuss the articles in groups and make written and oral reports on various aspects of the topic, including how we know what we know and how it affects us and our society. Finally we have time to design, implement, and interpret experiments related to that topic.

Although limiting ourselves to 5–7 topics would appear to limit the scope of Earth Science topics that can be covered, in practice most key Earth Science concepts are important in understanding these 5–7 topics. For example, key concepts in my more traditional geology courses include principles of stratigraphy, plate tectonics, and chemical differentiation. These three concepts are important in just one of the topics from the most recent term of Earth Science Today. Dinosaur radiation and extinction. Recent findings of dinosaurs with striking similarities on what was formerly thought to be isolated continents casts light on plate tectonics. Stratigraphy is important in understanding environmental change through time and how that relates to dinosaur life and extinction. The Ir layer at the K–T boundary has little meaning without an understanding of Earth's chemical differentiation.

Critical thinking, Science Reasoning, and Earth Science Basics tests were given to students in this course in an effort to track its success (relative to more traditional courses) in teaching students about the fundamentals of Earth Science. Results suggested that the course is more successful than most courses in teaching Science Reasoning. Results of the Earth Science Basics tests were not available at this writing.

An Earth System Science Education Program for the Inter-American Institute for Global Change Research.

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The Inter-American Institute for Global Change Research (IAI) is an international cooperative effort among 16 countries in the Americas seeking to improve their understanding of relevant global change phenomena. The 1992 United Nations Conference on Environment and Development (UNCED) focused attention on global change as one of the most critical challenges facing the world today. Evidence of natural and human induced change such as ozone depletion, loss of biodiversity and changing climatic conditions can be seen throughout the world, without respect for geopolitical boundaries. In recognition of the importance of a regional approach to the study of global change, the Institute's Science Agenda reflects environmental issues which affect the physical territories and socioeconomic systems of the IAI Member Nations. Education and training are a component of the overall IAI effort, and the USRA Earth System Science Education (ESSE) Program was selected to develop further the concept of an ESSE counterpart in the IAI structure. Central to the common interests of both ESSE and IAI are the educational challenges and opportunities which Earth System Science and Global Change present. The ongoing ESSE Program proposes to be a model for the development of similar collaborative efforts within the IAI member countries, tailored to the specific technical capabilities and scientific interests of the IAI participants. The existing scientific, technical and support resources of the ESSE program will be available to share with the ESSE-IAI team to facilitate an immediate, effective initiation of the proposed program. Members of the ESSE community are in contact with colleagues in the IAI member countries, and are exploring national programs, institutions and capabilities which will contribute to the planning process. Planning meetings were held in early 1997 to assess the educational needs of the IAI, inventory the existing capabilities and resources, and prepare a course of action that provides for collaborative university efforts that can address those needs. The meetings served to disseminate information about current educational programs and formed the nucleus of a network of educators, researchers, students and other individuals interested in Earth System Science and Global Change education topics which can be applied to the needs of the IAI member countries. A core educational program in Global Change including the creation of a WWW server specifically for the needs of the IAI will be proposed, and alternative means of data and educational module dissemination will be explored, such as by magnetic tape, CD-ROM etc. An important benefit of the Phase II proposal for the IAI, September, 1997, could be the establishment of a working relationship between the current ESSE community and IAI member educators and researchers. The project facilitates contact and dialog between individuals and fosters partnerships among institutions focused on understanding the Earth as a system.

Constructivist Instruction and Small Group Learning.

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At Virginia Tech, we have completely revised the laboratory exercises used in our introductory Physical Geology course according to constructivist instructional techniques and small-group learning. Our course objectives have shifted from memorized product (e.g., Know these minerals.) to reasoned process (e.g., Is it sedimentary, igneous or metamorphic and why?). What sets this course apart from similar projects is the sheer numbers of students who enroll in our introductory laboratory course—in excess of 1200 annually.

Many of the exercises begin with a small-group discussion that is centered around an open-ended question that pertains directly to the objectives of the laboratory exercise. Students are encouraged to gather information from multiple sources but must report back to class as a group within a few minutes. This discussion serves several purposes: 1.) It acknowledges that each student comes to the classroom with prior knowledge (including misconceptions); 2.) Student inquiry replaces the introductory paragraphs of traditional laboratory manuals that "tell" the answer; 3.) Student groups construct their knowledge independently from "packaged facts" and "right answers"; 4.) Student groups must divide tasks, and 5.) The instructor's role is that of facilitator—not lecturer. The exercises continue with students participating in simple experiments and/or by observing and responding to geologic materials. Most exercises conclude with a summary problem using concepts introduced in both the current and previous exercises. This portion of the exercise enforces the cumulative nature of scientific fact in constructing knowledge.

To promote the importance of understanding basic geological concepts as applied to local community planning, an independent group-based term project was added to the curriculum. The objective of the project was to encourage students to tackle issues and concerns related to our local geology in a manner that models how scientists, researchers, community leaders and local advocates collect data and combine it with published information to "get smart" about their local environment. Group work was chosen, in part to encourage collaboration, discipline and responsibility, but also to lessen the impact of up to 1000 students on our local geoscientific and professional community and to ensure that the instructors' grading load is manageable. Assignments include submitting a preliminary and revised proposal, a progress report, keeping a team portfolio, submitting a preliminary and revised abstract and presenting their results orally, professional meeting-style.

To acquaint new and returning TA instructors with the revised laboratory curriculum, alternative teaching models, and with current reforms in science education, we convene a one-day workshop at the beginning of each fall term. Our workshop is followed by weekly TA meetings in which the upcoming laboratory exercises are reviewed, alternative teaching techniques discussed and feedback received on the previous weeks' exercise.

Our results have been very encouraging. TAs who teach follow-up laboratory courses report that retention of skills such as disciplined observation of samples is vastly improved and that students commonly and willingly work together to discuss and solve problems. Several students have appreciated the independent, community-based group term projects indicating that they had never had to "get their own data" and "had no idea how to tackle a problem that didn't have an answer in the library." Perhaps the most satisfying response has been echoed on evaluations since we began revising the labs in 1993. As one student put it: "I listen in lecture but I learn in lab."

Mitigation of the Effects of Drought and Flood Disaster.

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In studying natural disasters, which have their source in the physical environment, it is fundamentally important to recognise that disaster is only possible in the presence of a vulnerable human community. Without human presence these extreme events would simply be regarded as geophysical phenomena. In learning about the Earth as a system, natural disasters offer an excellent context for demonstrating the interaction of the natural and human elements which constitute the system. This paper explores the range of actions that are possible for mitigating the effects of drought and flood disasters, and relates them to the Karoo environment of South Africa, a semi-arid region with extensive sheep farming and limited agriculture.

With the exception of some types of coastal flooding in which tectonic processes and high winds play a role, droughts and floods that occur in nature have their origin in the variation of rainfall beyond expected limits in which both amount and time are definitive factors.

Intervention directed toward affecting the cause of disaster in the geophysical realm is technologically oriented and more or less limited to cloud seeding which has had very moderate success. Intervention in the field of human occupation of hazardous areas and their activities presents more options. These include abatement schemes designed to reduce flood flows, e.g. by land-use design such as catchment area afforestation in relation to floods, and environmental conservation in relation to both floods and droughts. Modifying the hazard is another approach to disaster reduction. Such measures include constructing reservoirs (for flood control and irrigation during drought); constructing dikes and floodwalls to contain or divert flood water; conserving surface water and sinking boreholes as safeguards against drought; and adopting sound drought management principles. Mitigation can also be achieved by modifying the loss potential. Measures include statutory requirements and guidelines, design specifications, land-use control, zoning ordinances, building codes, warning systems, the application of water restrictions, or at the level of individual managers, diversifying sources of income and farm production, stockpiling fodder, introducing economies such as improving the quality of livestock or crops, as well as economies of scale such as enlarging the farming enterprise. Mitigation of the effects of disasters can be achieved by spreading the losses through society in the operation of aid schemes and planning for losses such as accumulating reserve funds or insurance against loss, in the absence of which the losses simply have to be borne by those affected. The ultimate step in disaster mitigation is total avoidance which is achieved by the permanent evacuation of hazardous areas.

In a pedagogic context the above measures can be used as a framework for discussion, extension and more detailed elaboration as they relate to local conditions. The emphasis of the learning experience should be on the need to understand the natural processes which constitute the sources of disastrous events, the recognition of hazardous locations, and on the role of mitigatory adjustments in the sphere of human activities and human occupation of disaster-prone locations. It should be recognised that hazard levels are rising as the pressure of population growth induces increasing numbers of people to occupy hazardous areas.

Earth System Science Education in the Field: The Cwmrheidol Mine; Mid-Wales, U.K.

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The Rheidol Valley in western Mid Wales, U.K. affords many opportunities for field study of the interaction between the hydrosphere, biosphere and the physical environment. A particularly fine example is provided by the Cwmrheidol mine where the impact of the now extinct metal mining industry on the Mid Wales area can be studied.

Mining for metals, principally lead and zinc, was an important industry in Mid Wales from the 16th century and reached its zenith in the late 19th century. It has had a significant effect on the landscape of the area and also a major effect on the ecology of the rivers in Mid Wales. The mines exploited the many sulphide ore veins and the ensuing pollution from the mines has been a cause for concern since the 1920s. Groundwater flowing through mine excavations reacts with the minerals left in the rock, becomes contaminated by the dissolution of heavy metals, and is acidified by the release of sulphur.

. The Cwmrheidol mine was worked for zinc until its abandonment in 1912. It provides a very graphic illustration of pollution from mines as the high pyrite content of the vein has resulted in iron stained spoil heaps and has caused an orange ferruginous mud to flow from the mine. The water leaching from the mine has a pH of 3.5 and a high concentration of heavy metals (140 times the UK environmental quality standard for dissolved zinc). This polluted water then flows through a number of largely ineffective remedial measures into the River Rheidol.

School students on courses in Geography, Biology, Environmental Science & Geology have all used the site to investigate the cause and effects of the pollution emanating from the two adits at the mine. The opportunities for study include: the identification of the minerals that are the cause of the problem; chemical and biological analysis of the pollution and river water; vegetation and soil surveys of the spoil heaps; investigation of the effects of the hydroelectric power scheme that diverts river water away from the site and the efficiency of remedial measures used at the mine. The mine has proved its effectiveness in clearly illustrating the interactions between different parts of the natural environment and the effects of human activity on the earth systems. Similar situations can be found throughout the world and used to integrate understanding of the interaction between earth systems.

The site is a flexible resource that has been used for teaching different disciplines. However, the greatest understanding of the site and its problems comes from learning about the interactions between different subsystems of the earth.

Earth System Sciences Course at Potsdam University.

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Since 1994, the author has lectured on Earth System Sciences for students in geoecology and geography. The curriculum is based on the following main parts:

(1) Evolution of the Earth System (formation of the Earth, biogeochemical cycles, faint young sun paradox, geo-engineering, terraforming)

(2) Modelling the Ecosystem Earth (Gaia-hypothesis, daisy world models, life span of the biosphere)

(3) Evolution models of the Club of Rome (anthropogenic effects, exponential growth, resources, sustainable development, sustainable geology, computer scenario)

The author uses copier films, videos and computer demonstrations with help of an overlay for the projector. The main aim of the course is to show both the evolution of the Earth System at planetary time scales and the effects of anthropogenic action within this system.

Role of Scientific Research Work for Specialist-Geologist Formation.

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The transfer of knowledge from professor to student to create a specialist is usually realized in two ways: lectures, seminars, etc., and independent research work by the student. The first way is traditional and necessary at the beginning of education. But only this way is not enough—this is mostly passive assimilation of the professor's knowledge without the student's initiative – it holds very little possibility to form a creative person. Usually specialists prepared according to the first way have certain knowledge and skills and can use them in future practical work for solution of standard problems. However in life there are a lot of situations when such a sum of knowledge is not enough. The second way is favorable for creating a person/specialist who can solve non-standard problems. Formation of such a specialist begins from the very beginning of education—the programme includes both lectures and seminars etc. And supervised independent research work. During the 1st year this consists of compiling a review on some scientific problem or question. After the 1st and 2nd years students have field training which is obligatory for all specializations of Geological Faculty (G.F.). During these educational field trainings, students investigate geological processes and are instructed by professors on how to understand them. After the 1st year during 4 weeks they study geological processes at the southern seashore of Crimea; after the 2nd year during 6–8 weeks (it depends on the specialization) they have training on geological mapping on the western flank of the Crimea Range. A final stage for both practices is preparing and defending a report on the research work. Field geology has always been and is now an essential part of geological training, requiring the development of a wide range of skills together with integration and interpretation of diverse data.

G.F. consists of 4 sections: geology, geochemistry, geophysics, hydrogeology and engineering geology. Since they have different subjects and specific methods of investigations, departments of every section organize, after 2nd and 3rd years, more special field training near Moscow (on Southern Urals, Northern Caucasus) and laboratory practice in research institutes. A new type of training is international practice: a "Floating University" for students and teachers of different specializations from universities of Russia and European countries. So drawing students into research work on G.F. is already a component of the standard educational programme. Students also have two industrial practices (after the 3rd and 4th years) where they work in industry, research institutes, etc.

Participation in educational and industrial practice is only the first stage of scientific investigation. The next stage is laboratory study of field collected materials. At this stage students master new methods on the modern equipment . They must also work in a library to be acquainted with published results of research work and new ideas in the field of their investigation. This stage is terminated by preparing/writing and defending the undergraduate diploma or graduate thesis.

A special type of specialist's formation is participation in students' and young specialists' scientific conferences, which take place in the G.F., universities or Ministry. At these conferences students not only present results of their investigation but, what is very important, ask and answer questions and defend their point of view .

Students preparing their theses usually work in the research teams of the department and these theses are part of a team's investigation. When the results of a team's investigation are published, the student can be one of the co-authors. Every year at the G.F. there are 12–15 of such publications. So, formation of a scientific mentality of students begins from the first steps of the educational process and is very favorable for formation of a creative person who can continue his education on a 2-year MSc programme. This programme includes one semester (half a year) for lectures and seminars and 1.5 years for independent research work. The level of MSc thesis sometimes is so high that they are recommended by a special commission to present and defend as a PhD thesis.

We believe that cooperation of study and research work is the best method of education at the present time. On the other hand, this requires the G.F. to create for all students the possibility for scientific intelligence and search. To realize our programme, the G.F. for many years has sent the most talented students (according to the recommendation of the department), to appropriate universities of Europe and the USA.

Session Summary IIB

This summary was combined by the Coordinator with that of IID. It appears at the end of Session IID.

Session IIC: Using Technology in the K-12 Classroom

Daniel Barstow and Asta Thorleifsdottir, Moderators

Classroom-accessible technologies hold great potential for demonstrating the interdisciplinary interactions of Earth systems that may otherwise be difficult for students to visualize. A number of national (US) programs involve students in use of technology for data access and collection, numerical and image manipulation, and addition to databases that scientists can use; others teach the use of model-building software for demonstrating linkages between Earth processes and outcomes, or describe innovative multimedia presentations toward that end. In addition, the resources of the internet offer access to Earth images, real time data, and cross-curricular links. Home pages for data access and information exchange were described with attention to their use by K–12 classrooms.

Using the Internet to Teach Earthquakes and Plate Tectonics.

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Texts for Middle and High School, including many first year general Geology college texts, either teach plate tectonics and earthquakes as separate topics or refer to earthquakes as most commonly occurring along major tectonic zones, outlining the plate boundaries. Students actually have very little evidence to support the concept that quakes outline plate boundaries. In addition, other earthquake related information, such as the concept of using magnitudes of quakes to outline different plate boundaries, requires only passing statements in text materials. Another area of concern for today's students is the familiarity with longitude/latitude locations and other mapping skills useful for determining various geographical and geological sites throughout the globe. Also, many students perceive the subject of geology as dealing with events of the past with little emphasis on recent occurrences; the ability of schools and individuals to access recent information has greatly improved with the availability of computer online data sources.

In this activity, online data bases from the USGS through an html address, *gopher://gldfs.cr.usgs.gov:79/Oquake*, students can down load earthquake information that gives site locations and near real time international information. For each earthquake, epicenter longitude and latitude are given along with depth in kilometers to the focus, time in Universal Time, magnitude, and general location. To visit this site students must have access to the Science Department Computer Lab, a computer with Netscape, and a printer to download and print out the information about the quakes. Using a world map with general longitude and latitude, students plot the location of the quakes using different colored pencils for various magnitude ranges which they have predetermined as representing different types of plate boundaries. Using this information for a few minutes every third day for a semester, students were able to plot most of the major plate boundaries and began to initiate other questions regarding earthquakes. Frequency of earthquakes and magnitudes led to additional questions that included why some locations had more quakes than other sites and what was the relationship between focus and epicenter distances and quake magnitudes. Students also began reading the newspapers and watching the news for information regarding the quakes downloaded from the Oquake source. The work with this web site led to questions regarding information from other potential sites including a more encompassing program from the University of Michigan. Students in these classes represented a variety of ability levels; these experiences generated good participation responses from all of the students. Even students who had not previously taken the course work seriously looked forward to using the computers and completing the work with the maps. Additional projects generated by the students included the prediction of quakes, particularly severe quakes in certain areas of the world. This project illustrated the positive effects of combining technology with a variety of topics including mapping, earth science concepts, and simple statistics, which led to student understanding of geological processes as ongoing current events, and served as a "lead-in" to the study of folding and faulting.

Explore Kilauea Volcano, An Interdisciplinary Educational CD-ROM.

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"Explore Kilauea Volcano, Living Land of Hawai'i" is an interactive educational CD-ROM which offers a comprehensive interdisciplinary study of Kilauea, the world's most active volcano. The CD-ROM explores the volcano through a study of its component parts as well as its relationship to the larger earth system. The most detailed aspect of the program is a virtual reality documentation of fourteen trails across the Kilauea Volcano. These hikable trails are annotated with images of specific plants, geologic features and trail guides encountered along the way. Incorporating several texts, including "A Teacher's Guide to the Geology of Hawai'i Volcanoes National Park," the presentation structure of the CD-ROM is designed to reflect the relationships between the volcano, its geologic structure, eruptions, ecosystem, and culture. Issues in designing and using interactive media for interdisciplinary education were also discussed.

For more information about the program please visit our web site: *http://www.fireworkstudios.com*

The Importance of Systems Modeling in Earth Science Education.

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To understand the Earth as a system researchers need to investigate interactions among the variety of data gathered by Earth observing instruments. Whether the researcher is novice or expert, designing an Earth system science research plan requires the efficient browsing of large volumes of data for a variety of parameters with extended spatio- temporal coverage. Scientists have access to a variety of tools and technicians to browse these data and decide on a research plan. This is not the case in the education context: students in high school and undergraduate settings often do not have access to a team of programmers and data visualization experts. And while the time and expertise available to students is limited, their requirements for creating a research plan are generally the same as those of the scientist: efficient browsing of large volumes of data for a variety of parameters with extended spatio- temporal coverage. A list of major obstacles to intercomparison studies of Earth system parameters includes: a) broad variety of data formats, b) variety of spatio- temporal resolutions, c) enormous file sizes, d) georeferencing, e) incomplete, poor, or highly specialized documentation, f) mastery of visualization software.

An example may serve to illustrate this issue. Students in my ESS class wanted to investigate the relationship between stratospheric ozone and phytoplankton pigment concentration to see whether diminishing ozone values have an effect on phytoplankton populations. A preliminary examination of data from NASA's TOMS and CZCS missions indicated coincident temporal and spatial coverage but different spatial resolutions, and different data formats. The necessity of reformatting and regridding the data was not beyond the students' understanding, but certainly beyond the limitations of time and expertise available to them.

The Earth System Visualizer (ESV) is designed to meet the challenges posed by research oriented Earth system science courses. The ESV will also satisfy the general needs of research planning, at a preliminary level, by enabling users to visualize and intercompare data from a variety of parameters.

Using Space Shuttle Photos to Help Students Visualize and Investigate Earth Systems.

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Over the past 15 years, space shuttle astronauts have taken over 250,000 photos of Earth, using high resolution cameras. These photos depict, in many cases with stunning clarity, land features, ocean currents, cloud patterns, air and water pollution, fault lines, drainage patterns, ice flows, and numerous other physical features of the Earth. These photos are an outstanding, and inexpensive, resource to help students visualize and investigate Earth systems. Students directly observe and investigate the realities of the atmospheric, hydrologic and geologic processes at work, and how they interact in complex yet tangible ways.

The educational use of these shuttle photos, along with satellite remote-sensing, computer-based Geographic Information Systems and other visualization technologies, are the focus of "Visualizing Earth," a research project funded by the National Science Foundation. In this three-year project, an interdisciplinary team of scientists, educators, and cognitive psychologists are investigating the revolutionary power of these visualization tools and resources. Our goal is to lay a strong foundation for more effective and wide-spread use of such geographic visualizations in K–12 education.

In this poster session, we focused on the shuttle photos, which we have found to be an especially powerful entry point to the study of Earth systems. We presented several examples showing how such photos can be used to promote inquiry-based student investigations. Students explore erosion and deposition in the Nile and Mississippi River deltas; the climatological effects of Oahu's island weather patterns; plate tectonics as dramatically seen in the fault lines of Southern California; and the impact of local topography on global weather patterns as a storm system moves across central US. The images spark student investigations, and the students' understandings deepen as their investigations unfold.

The shuttle photos also provide a context for discussing the three domains of our research:

1) Cognition—research in cognition and perception to better understand the developmental process as students learn to use such images and tools, and how advanced visualization tools can help them progress more rapidly and effectively.

2) Curriculum—research into the most effective approaches to curriculum design to help teachers and students integrate these tools and resources, with a special emphasis on inquiry-based learning.

3) Technology—exploring advances in visualization technology, to tap into its power to represent complex information and to make sure the technology is simple enough for school use.

New technologies of space-based photography, remote-sensing, and animated visualizations have revolutionized how scientists investigate Earth. We believe that these advances in the tools of visualization, and the wealth of data that can be investigated with these tools, will have a similar revolution in education. Ultimately, they can have a profound impact on how students visualize, explore, and understand our marvelous planet.

Internet-Based Earth/Space Science Instructional Strategies.

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Many US government agencies, such as NASA, USGS, NOAA, as well as many US commercial organizations, such as CNN, USA Today, and The Weather Channel, provide up-to-the-minute data and digital images readily accessible on the World Wide Web. These web pages, among many others, represent an enormous resource for classroom teachers. However, some of these resources are not immediately useful to classroom teacher without significant modification. The Montana State University Net Teach Talent Network Materials and Professional Development Laboratory is developing earth/space science instructional materials for K–12 classrooms that utilize Internet-based resources *(http://math.montana.edu/~dave/ntt/)*. These student-centered activities focus on scientific investigations using current data. Advances in hypermedia as an instructional tool for science education provide a teacher-friendly mechanism for designing user-friendly classroom units based on available data. Working in teams, scientists and teachers collaboratively create and develop lessons in HTML format that prompt a learner to get information from specified, hyperlinked WWW resources to formulate and investigate a scientific question.

Two instructional models used by the development teams that are grounded in constructivist instructional theories are the Learning Cycle Model and the Investigation/Experimentation Model. The Learning Cycle model seems to be most appropriate when the focus of the lesson is to introduce new scientific concepts to learners. This model works well to support traditional textbook instruction. Teacher-facilitators guide the development of accurate scientific conceptions actively generated by students using the WWW and reinforced by applications to new questions. The Investigation/Experimentation model seems to be most appropriate when the focus of the lesson is to address specific questions about nature. This model works well when learners are viewing data that has patterns or attributes that lend themselves to testing predictions and testing hypotheses. This model encourages students to formulate and investigate their own questions, especially when used with interactive forms (e.g., cgi scripts) to share data with students at remote locations.

The materials development is conducted in a three-phase process. First, scientists outline, review and summarize important scientific concepts for small groups of teachers. Second, teachers work together to identify aspects of a concept that are appropriate for classroom use and format the investigation in an effective pedagogical format. Third, the participating scientists work collaboratively with the teachers to insure the accuracy and emphasis of the scientific content and adherence to US National Science Education Standards. Examples of earth system science lessons currently undergoing development for the National Science Foundation's Network Montana Project that focus on electronically-updated seismic networks, NexRad radar, remote sensing satellite images, and Geographic Information Systems data can be found at *http://math.montana.edu/~dave/nmp/*. Examples of space science lessons currently undergoing development for the NASA Yohkoh Public Outreach Project focusing on current solar images can be found at *http://www.space.lockheed.com/YPOP/*.

The GLOBE Program: Connecting the World Science and Education Communities.

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The GLOBE (Global Learning and Observations to Benefit the Environment) program is a collaboration between scientists, educators, and K–12 (or equivalent) students working in a worldwide network to better understand the current condition and possible future evolution of the environment of our planet. Science and education are equal partners in GLOBE. The objectives of the GLOBE program are to 1) enhance environmental awareness of individuals worldwide, 2) increase scientific understanding of the earth, and 3) help all students reach higher standards in science and mathematics.

The primary mode of communication in the GLOBE program is the World Wide Web. Scientific protocols and learning activities, as well as visualization products and relevant web links are provided *(see http://www.globe.gov)*. In addition, students from around the globe have access to scientists involved in the analysis of the data being collected.

Over 100 scientists from around the world were involved in identifying a list of science measurements that would make a significant contribution to the global environmental data base. Teachers from GLOBE-participating schools attend regional workshops to learn how to teach measurement procedures, how to apply the GLOBE data-reporting technology, and how to use GLOBE visualization products as instructional material. The intensive 3-1/2 day workshops familiarize teachers with all of the instrumentation necessary to make GLOBE core measurements. In addition, there is extensive computer training to introduce teachers to the GLOBE software and reporting and communicating on the Internet.

Educators and scientists have developed, and continue to refine, age-appropriate educational materials for use in GLOBE schools to complement the student measurement, observation, and analysis activities. These materials are intended to guide students through a progressive learning experience to ensure both skill development and improved understanding of science and scientific analysis. Special attention is paid to preparing materials that are readily adaptable into a wide range of cultures, languages, and socio-economic circumstances.

Image Processing.

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Teaching image processing to middle school students extends their competence on the computer beyond word processing skills and data retrieval over the internet. They learn to use the computer as a tool to analyze images and to draw conclusions based on the analyses of the images. They also learn to prepare reports, and to use spreadsheets for calculations and graphing.

My eighth grade students use the NIH Image application software to analyze images from NOAA, NASA, and other current sources. They try to answer hypotheses they developed about various problems, including global change. The goal of the unit is for the students to demonstrate their expertise of the NIH Image software, word processing and spreadsheet use. Working in teams of two, they produce a computer-generated report of their findings, including illustrations, tables and graphs, and a discussion of the methods they used in the image analysis. While I do not limit the students in their choices of images, many choose satellite images of earth systems that enable them to explore global changes in the environment.

Over the past two years I have developed a 6-week image processing unit for my eighth grade earth science classes. This year I have purchased computer hardware that will enable the students to capture their own images for analysis, such as cloud formations, insect damaged leaves, and microscopic views of soil and soil organisms. We do not yet have Internet access at our school district, but I am learning how to find and download images on my computer system at home. We will be connected to the Internet within the next two years, and so I am planning to make this part of the image processing unit in the future. I would like my students to be able to produce their final product completely from the computer lab, including gathering background information and downloading their own images to analyze.

I took part in a one-week training session given by the Center for Image Processing (CIPE) at the University of Arizona, Department of Planetary Sciences, in the summer of 1993. I am licensed to use the material prepared by CIPE, and am working to become certified as an instructor.

Natural Disasters and Society.

Asta Thorleifsdottir, Menntaskolinn vid Sund, IS-104, Reykjavik, ICELAND PS.Alfheivar 62.

My students and I developed a homepage *(URL: http://www.islandia.is/hamfarir/)* that defines and clarifies causes and effects of natural disasters. Such disasters are caused by weather, geological circumstances and humans and are explained by religion, myths and science. They affect the economy, social structures and mental health of societies, with effects differing from the poverty stricken to the wealthy societies.

INTRODUCTION

This is a crosscurricular and interdisciplinary study developed from studies on Iceland's nature and interest in travel, geology, and geophysics. The aim is to gather data on natural disasters, classify statistically, and study demographic effects as well as social implications. The project was motivated by the extent of information we pour into our secondary school students without ever linking different subjects together. My students and I decided to gather information world wide, sort it and make it available by setting up a homepage on the World Wide Web.

The homepage is stationed with a server in Reykjavik and is accessible over the Internet, free of charge. The major keywords are: meteorological causes, avalanches, lightning, forest fires, drift ice, droughts, erosion, storms, floods, anthropogenic causes, nuclear materials, ecological changes, greenhouse effects, ozone depletion, acid rain levels, geological causes, volcanic eruptions, earthquakes, landslides, economic effects, property or life, different values social effects, the shock, first effect, long term effect, social situation, living in disaster areas, ideological discussion, religious explanations, the work of darkness, legends and myths, the modern scientific view, links to pages on earthquakes, lightning, ozone depletion, avalanches.

A databank is under constant construction, therefore this plan may include features intended but not yet in place. The main structure:

=> World maps, tectonic, earthquake, volcano…

=> Geological causes of natural disasters (Icelandic volcanoes, Volcanoes abroad. We survey earthquakes, landslides, quicksand, fires, tsunamis…and link to history.)

=> Meteorological causes of natural disasters (Avalanches, rainstorms and lightning, forest fires, drift ice, droughts, floods in oceans, lakes and rivers are all caused by extremes in the weather. The greenhouse effect, ozone depletion and acid rain can increase or decrease from meteorological influence. Or are the causes anthropogenic?)

=> Anthropogenic causes of disasters (By changing their surroundings to make them fit their needs, humans may cause or aggravate natural disasters. Nuclear power, drainage, reservoirs…)

=> Economic effects of natural disasters (Economic effects are usually measured in the damage of property. The earthquake of Kobe cost nearly half of the annual insurance damages that one of the world's biggest reinsurance companies paid out in 1995. It estimates a deathtoll of 18 thousand in natural disasters, but The Red Cross estimates 150 thousand, mainly in poverty stricken societies.)

=> Social effects of natural disasters (Research demonstrates that societies and individuals face a similar process following a natural disasters, with the initial shock, the numbness. The survivors participate in the rescue, stick together, and are extremely helpful. They encourage, fight, support. They form the most remarkable talents humans have, and yet the most frightening—the denial.)

=> Ideological discussion on natural disasters (From time immemorial humans have tried to explain and justify natural disasters. The overpowering effect of nature craved explanation. These needs are demonstrated in myths, folk lore and religion. The modern view provides rational answers. We seek explanation for some great disasters, such as the plagues of Egypt, Atlantis, the diluvian period of Noah. The Bible was used to pacify a hungry and threatened population with pious explanations. We explore answers and explanations given in the late 18th century when the greatest eruption in modern times occurred in Iceland.)

=> Links to related topics (On this page we catalogue several homepages on similar matters.)

Learning Through Playing: The Greenhouse Effect in 'SimEarth': the Features of Learning Process and Outcomes.

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'SimEarth', an interactive simulation game software, seems to be helpful in realizing the whole Earth as interacting systems, because this simulation provides interactive operations on several variables which affect the SimEarth's environment. Students can easily observe the changes in basic indexes such as atmospheric temperature as a result of interactions within subsystems. The focus of this report is the possibility of using this game in the classroom. In order to reveal how students learn about the Earth systems, what is effective and what is difficult in using this game, I have chosen the greenhouse effect as a topic, developed six game-centered activities including concept mapping and prepared a questionnaire. Assumptions underlying the approach to this report are that knowledge is organized by constructive processes and we are able to specify what students learn by analyzing the relationship between concepts in the maps.

The series of activities focusses on Earth Systems Understandings 2 and 4 (Mayer, 1991). The significant parameters of SimEarth are tuned up and some restrictions on the operations are placed for each activity. On an individual base, 11 students ages 16 to 18 were involved in playing the game by following self-explanatory instructions on the sheets. At the end of each activity, students were asked to express what they learn through playing in diagrams to create or revise concept maps (conceptual schemata or webs). Six activities are "Beginner's," "Frozen Planet," "Volcanic Activity," "Afforestation," "Human Activity," and "Final" course.

It took 20 minutes to play the game, 8 minutes to draw a diagram and 12 minutes to create or revise a concept map on average. The learning occurring during those processes can be monitored by analyzing the growing concept maps as they are revised by students. According to the growth, linkages in the map have been concentrating in specific concept: "Carbon Dioxide" (7 students), "Atmospheric Temperature" (2 students) and "Population" (1 student). Ten out of 11 students successfully understood about organic (or biological) inorganic (or geological/physical/chemical) and social (or human related) interactions found in the Earth systems concerned with the greenhouse effect.

By analyzing the specific concepts and linkages in diagrams, I found that students observed some exaggerations such as evaporation of sea water and observed long-term warming caused by volcanic gases instead of short-term cooling by ash. These difficulties may be overcome by tuning SimEarth up and revising the worksheet. Nuclear power and the Third World are developing controversial issues. Discussion may be inevitable in the senior high school classroom. Therefore this series of activities should be followed by discussion.

Student's perceptions of the greenhouse effect were surveyed before and after the implementation, using questionnaires about the cause, consequence and possible cures of global warming, based on the study of Boyes et al. (1993). In the responses for the open-form questions, correct statements increased. Students who mentioned "Afforestation" as a cure increased by 5, while those who mentioned "Volcanic Activity" as a cause increased by 8.

Correct responses for closed-form questions about the cause increased. The number of students who thought that "Population Growth," "Powerful Volcanic Eruptions" and "Industrialization in Developing Countries" would make global warming worse, conspicuously increased. Students increased by 5 to 8 who did not deny that the greenhouse effect can be made smaller by having nuclear power stations instead of coal power stations. As for cures, correct or appropriate responses decreased. In the minds of students there seemed to be confusion over the interrelation between the factors. Cooperative learning may disentangle the confusion.

In conclusion, learning processes show that students successfully understand about the interactions within subsystems through playing and may imply that it is necessary for teachers to provide a key concept such as "Carbon Dioxide" which is included in all the spheres for easier understanding of whole Earth systems. I think it is useful to use this game in the classroom, if we tune SimEarth up to avoid showing an extreme environment. Also, cooperative learning, mapping and discussion are necessary for effective use of this game.

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The Internet as an Educational Tool: Web Browser Interface for Viewing NASA Shuttle Laser Altimeter Data.

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The Geodynamics Branch of the Laboratory for Terrestrial Physics, located at NASA's Goddard Space Flight Center, is making geophysical data sets and interactive visualization tools available through its WWW homepage *(http://denali.gsfc.nasa.gov)*. Our aim is to provide a resource for the enhancement of technological and scientific understanding and involvement at all educational and interest levels. The data and software tools provided can be used by researchers, educators, students and the general public to experience geophysics research activities being performed at Goddard. For example, data acquired by the first Shuttle Laser Altimeter (SLA-01) flown on STS-72 during January 1996 and the SLA-02 flight in August 1997 on STS-85 are available. The SLA instrument precisely measures the distance to the Earth's surface from the Space Shuttle by means of laser ranging. The data has wide applications in a variety of Earth-science disciplines ranging from topography studies to atmospheric remote sensing. Specifically the data can be used to study many Earth System Science applications including:

- OCEANOGRAPHY—wave studies
- HAZARDS—coastal erosion
- GEOMORPHOLOGY—drainage evolution
- GEODYNAMICS—regional tilts
- CLIMATOLOGY—cloud top heights
- SEISMICITY—fault scarps
- VOLCANOLOGY—eruption plumes
- TECTONICS—mountain relief
- ECOLOGY—tree height, canopy structure
- HYDROLOGY—lake levels

We are designing and building a user friendly graphical interface for web access and manipulation of the data. Making the data and tools easily accessible and understandable is our goal. Data browser, plotting, and output utilities will be implemented using CGI scripts or JAVA to gather interactive user input. These inputs will then be used as parameters to spawn an Interactive Data Language (IDL) background routine to produce and display the requested output figure, chart or list. An online guestbook will also be provided to allow users to share their findings. Geophysical information and figures pertaining to Earth magnetics, gravity, and tectonics can also be found at the web site.

Designing Supportive Scientific Visualization for Learners: Adapting Scientists' Tools.

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Earth Systems Science educators seeking to provide their students with the opportunity to work with global data are typically faced with a choice between two options. They can devote considerable time and effort to teaching students to use powerful, yet difficult to use scientific visualization analysis packages, such as IDRISI, Transform, or IDL. Or they can provide them with simpler software, such as NIH Image or web based tools, that allow students to view data as imagery, but not to manipulate the data numerically. In recognition of that dilemma, the NSF sponsored SSciVEE (Supportive Scientific Visualization Environments for Education) Project has developed WorldWatcher for Macintosh. WorldWatcher is a visualization and analysis program for global, gridded data that was created specifically for use in educational settings. Developed through a collaboration of educational researchers, technologists, and geoscientists, WorldWatcher provides the support that learners require while providing many of the analysis features of scientists' tools.

WorldWatcher provides instructional designers with the ability to construct data collections that assemble related data sets into a module for teaching a specific set of topics. The first module that we have created is for studying energy balance and the possible causes and effects of global climate change. This "ClimateWatcher" module provides students with access to global data sets that incorporate atmospheric and related physical and human geographic data. The data includes:

- Climate: Insolation, Albedo, Absorbed/reflected solar energy, Surface temperature, Precipitation, Greenhouse effect/increase, Outgoing long wave radiation, Net energy balance
- Physical Geography: Elevation/Bathymetry, Ground cover, Plant energy absorption, Soil type
- Human Geography: Population density, Carbon emissions

WorldWatcher displays global data in the form of two-dimensional raster images in several projections. It supports both the interpretation and creation of data. Users can customize scientific visualizations by modifying the color scheme, the spatial resolution, and the magnification. New data can be created through mathematical operations (addition, subtraction, multiplication, division, correlation, minimum, and maximum), by "drawing" on visualizations using a paint program interface metaphor, or by using a simple climate model to explore hypothetical scenarios.

A Computer-Based Distance and On-Site Earth Science Course for Teachers.

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During the fall of 1996 we designed and produced a unique earth science course for in-service elementary and middle school teachers. We created twelve lessons on CD-ROM, and presented these at two sites during the spring semester. The weekly class meetings employed a three-part *"learning cycle"* format. Each class began with an *"exploration"* phase, contained a *"concept development"* phase, and ended with an *"application"* phase. This was accomplished through a mix of on-site activities conducted by master earth science teachers, and "lecture" segments on CD-ROM. Each class meeting was divided into three one-hour segments.

Segment 1 "***Exploration***"—Led by the master teacher, the participants were introduced to the evening's topic with a laboratory activity which allowed them to explore what they already knew about the topic and discover what they needed to learn. In general, these were activities which had been designed for use in high school and college earth science courses.

Segment 2 "***Concept Development***"—In order to understand the topic better, and to collect and organize important information about it, the participants spent the middle portion of the evening working in teams of two or three to explore and discuss the "lecture" material on the CD-ROM. The material was presented via concept maps which displayed each topic's main points and traced the links between the points As the class participants explored each map, information about the main points was presented through pictures, written text, animation and video.

Segment 3 "***Application***"—During the last hour the master teacher led a second set of activities designed to present the material in a form specifically designed for use with elementary and middle school children. Participation in these activities allowed the teachers to experience ways by which the information they gained could be applied in their classrooms.

The success of this course was carefully evaluated. Pre and post tests measured a significant increase in the teachers' knowledge of earth science and earth science teaching at each site. In addition, the tests revealed a significant increase in the teachers' desire to teach earth science, and their confidence in their ability to do so.

Session Summary IIC: Using Technology in the K–12 Curriculum.

Summary prepared by E. Barbara Klemm based on notes from discussion leaders Klemm, Daniel Barstow, and Asta Thorleifsdottir.

"It's great to have information-rich web sites available to us," and "We want to be able to continue having access to these" were comments echoed in all three discussion groups following the poster presentation. Advantages to distance learning technology (DLT) include savings in terms of gas and time to travel to various sites to teach. DLT is a way to reach out and serve disabled as well as distant and underserved groups. At its best, DLT may be a great leveler of content and opportunities, assuming that institutions with assets (including "hot" professors) are willing to fund costs.

There is really no such thing as "Free on the Web." Setting up and maintaining a web page requires both time and resources. Web pages ought to be viewed as shared resources. Educators need to work to find ways to maintain them and keep them on-line. Administrators may not understand that internet access and instructional use of computers involves potential internet charges, maintenance of equipment, updating of software and eventually, replacement costs. Simple telephone access from rural areas may incur long distance charges on top of the cost for equipment, thus equitable access is an issue. One participant suggested that educators pointedly thank NASA and NOAA for resources they have made available.

Teachers' roles are shifting with these new technologies, decreasing the function of teachers as content deliverers and increasing their function in teaching critical thinking skills. A challenge for teachers using technology is to teach for understanding and connections, not just for knowing. Teachers pointed to the need for mixing virtual exploration with concrete encounters ranging from making models to real-world experiences. In particular, virtual encounters require students to visualize data using timelines, scatter plots, color-coded maps and images, and interpretation of two- and three-dimensional representations. Research is needed on choices made by teachers to present information and by students to select and use information in learning tasks. Cognitive barriers need to be identified and solutions devised and tested.

Educators must become more sophisticated about their research tools. Among research questions of interest were: What do students need in order to get some learning done using technology? How can data sources from the web be used to get them started without creating misconceptions or introducing falsehoods? How effective is use of remote images or multimedia presentations in terms of learner outcome, and how are researchers to determine this? What are the cultural implications of use of these technologies? What do teachers mean when they say they want students to engage in "authentic research"? What kinds of research are reasonable for K–12 students? Is our aim more to engage students in the authentic processes of scientific research rather than in research itself?

More teachers need to be engaged in using technology. Based on experience in the USA, only about 25% of K–12 teachers currently have access to technology, and as a guesstimate only about 25% of those use the technology. Models for engaging teachers in using technology include 1) technology training workshops for "alpha" teachers (those with technological access) aimed at their grade level, 2) workshops for teams of educators (elementary, secondary, college level) who agree to work together for change in an educational system, and 3) preparing teachers of teachers (e.g. the science methods instructors) to be catalysts and models for change.

Session IID: Innovative Approaches to Instruction about the Earth

Yael Kali and Lynda Samp, Moderators

In addition to short-term activities that help teach about the Earth as a system, conference participants in this session used entire curriculum approaches that change the style of teaching and the look of education about the Earth. Posters in this session described uses of art, music, mythology and other literature as instructional tools, outdoor laboratories and field camps as integrative experiences, use of maps, computer visualizations and remote sensing as aids to holistic learning, and cooperative techniques for team learning. Special attention was given to the aspects of learning that promote effective approaches to problem solving on Earth system issues. The applications presented are only the beginning of what can be done by creative teachers using the techniques.

Field Based Geology for 4th through 8th Grade Students: Learning by Completing Hands-On and Mind-On Activities.

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Students learn by thinking and achieving, not by listening. By accomplishing field investigations they retain more information about what they have collected and subsequently learn that all parts of the Earth are interrelated. For nine years the University of Colorado's Geology Department has worked with Colorado Springs District 11 to improve the science education of 4th through 8th grade students. Students are selected by the school district and are usually either gifted and talented students or students who have shown a strong interest in science and mathematics. During the past nine years over 1,000 students have completed this program. The program has evolved from a day long field class to courses that are held once a week for six to eight weeks.

The present course is designed so students can progress through the three- to five-year program while developing and improving their knowledge about Earth Science and the many ways its' processes can be observed and the concepts understood.

Each day begins with a 30- to 60-minute discussion period to insure the students understand the material to be investigated. School buses are used to transport the students to the selected field site. The students are required to take field notes and collect the necessary field data. This information is used to carry out an analysis and explanation of the field data. This analysis is to be completed and turned in the following week. Whenever possible the investigation includes mathematical and statistical determinations. Geologic and topographic maps are made available to the students. Often, articles from professional journals are assigned to be read the week before the field investigation starts.

In addition to the analysis of the field data, all notes recorded during the day are used to complete written descriptions of the work that has been completed. This work is evaluated for paragraph and sentence development, grammatical structure, spelling, and punctuation. This process has succeeded in improving the students' writing ability over the three to five years they have been involved in the program.

The curriculum is based on earth and environmental science topics. The following list of field investigation topics are included in the program: the water and rock cycle and their interrelationships; orientation of slopes and its relationship to weathering, vegetation, geomorphic processes, and soil development; resource availability, development, and use including mine reclamation; geologic hazards and mitigation of such hazards as flooding, landslides and avalanches, swelling soils, and mine collapse; cave development; mineral and rock origin and identification; topographic and geologic map development and interpretation; geologic history and fossil collecting; climatic and weather differences and their relationship to geologic processes and the development of landforms; human influences on geologic processes; mountain building with an emphasis on the areas relationship to plate tectonics: and how earth science can play a part in aesthetic determination. Although this is not a complete list of the topics being investigated during the courses, it is representative of the topics used to develop the student's understanding of earth and environmental sciences.

Field Oriented High School Courses.

Steven C. Kluge, Fox Lane High School, Box 390, Route 172, Bedford, NY 10506 USA.

Two unique Earth Science courses designed to involve students in original field studies and research are offered at Fox Lane High School in suburban Westchester County of New York State. The "middle" two-thirds of each ninth grade class are enrolled in the New York State Regents Earth Science course using the 1994 Program Modification Syllabus. Earth science teachers at the school designed, proposed, and had accepted by the State Education Department (SED) a 35% variance to the SED final exam that involves each student in an independent study of a stream on the campus. Students design and construct a stream gauging station and collect width, depth, velocity, and rainfall data over an extended period of time. They design individual spreadsheets to draw stream profiles, calculate discharges from their measurements, and examine rainfall and discharge trends. Students write a short paper explaining the significance of the variations and lag times evident in discharge rates over time. Spreadsheets and essays are handed in on a disk that becomes part of their final exam.

Earth Science II is an elective undergraduate level Physical Geology course offered to any interested senior and qualified juniors. The course includes an extensive two day field trip to examine the sedimentary rocks and associated structures, geologic and glacial history, and stream drainage development in the eastern Catskill Mountains. Students write a detailed report of their field experience, and the trip serves as the basis for in depth lab exercises throughout the remainder of the year. Two additional, optional field trips to the Adirondack Mountains are offered in the fall and spring as well. At the end of the year, students working alone or in teams of two develop a question about some geologic process occurring on or near our campus, suggest an answer, design and conduct an experiment to test the hypothesis, and report on the implications of the experimental results. This class draws between one quarter and one third of all the students in our school, and in the past 15 years more than 5% of these students have completed undergraduate or higher degrees in the Earth Science related fields.

National Parks Project.

Larry Rodgers, Chaparral Middle School, 4020 Poplar Lane, Chino Hills, CA 91789 USA.

Science is an active process and something that students do, not something that is done to them. Students need hands-on activities, as well as "minds-on" experiences. Students engaged in inquiry science learning describe objects and events, ask questions, construct explanations, and test and communicate those explanations comparing current scientific knowledge. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. Students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. They are prepared to discuss issues and make informed, responsible decisions.

President Theodore Roosevelt established our country's philosophy that the land in its natural state is one of our most precious national treasures. He believed that preserving examples of our country's finest landscapes, wildlife and waterways for present and future generations of Americans is of utmost importance. Roosevelt noticed the degradation of our countries landscapes and established the National Parks System. Several areas were evaluated and selected as our country's first National Parks.

In the National Parks Project, the task of the students is extremely important, environmentally essential, and invaluable for this country's future. The nonlecture based learning environment and alternative form of assessment is constructivist in nature. Students address many of the earth systems in an integrated, real world activity.

This multifaceted endeavor is open ended, and a situational experience for our students. The interdisciplinary project refines skills previously learned and relates to the students' life experiences. Attitudes and problem-solving skills useful for a lifetime are developed be the students. If tomorrow's adults are to make educated decisions concerning environmental issues and Earth, it is vital that today's students be given the opportunity to study at all levels Earth Science as an integrated part of education.

Student teams (in the National Park Project) will actually perform the tasks required in the selection of potential national park sites. Teams first investigate two existing national parks in their selected region, investigating geological, biological, hydrological, and historical features in the park. After several days of investigation the groups determine the criteria that made the area special enough to be selected above other potential sites.

Once the introductory exercise has been completed, each team surveys the region of the country they have selected and chooses a possible site unique or special enough to be considered as a national park. The area's geologic features and the processes by which it was formed and are currently altered must be investigated. Biological and botanical aspects are of major importance and must be of foremost consideration. The hydrological feature is an area's life-blood. It is an essential component that must be preserved for an area to retain its grandeur. All of an area's Earth Systems must be addressed by the students in their evaluation of an area for significant consideration. Historical significance, cultural, scientific or esthetic features must be included in the evaluation process.

Teams of four students design a new park for our country's national park system. Their park design will use background information and data collected on existing parks, plus the extensive data they obtain on their new location. Students are required to complete three major components:

1) A comprehensive, student-drawn topographic scale map of the chosen site location with all natural and man-made features.

2) A brochure that promotes the park's unique features: biological, botanical, geological, historical and cultural elements.

3) An extensive Environmental Impact Report evaluating the park and its effect on the proposed area.

Optional extension activities include:

1) A 3D model of the park design showing the features included on the national park scale map.

2) A proposed script of a ranger-guided activity including, but not limited to, animal and plant interactions, astronomy, geological formations, and the area's historical significance.

The culminating activity for this project will be a group presentation promoting the students' park design before a Park Selection Committee. This committee may include Park Service district personnel as well as parents and experts in the community. Multiple forms of assessment are integrated with teaching and often are indistinguishable from the instruction. The focus moves from the acquisition of facts to the ability to problem solve and apply those facts. More open-ended types of activities and performance based tasks allow students to demonstrate their knowledge of different concepts. This authentic type of assessment is appropriate for all levels of learners and creates an environment geared towards success.

Knowledge of our planet is important to all of us, for we all will call this place home for our entire lives, and all activities are related to interaction with the earth. Continued population growth and concomitant natural resources consumption impose stresses on our society. Our society's environmental future depends on understanding the earth to guide wise utilization of natural resource and prudent avoidance of natural hazards. Our citizens and leaders must understand how a finite earth with its finite resources imposes limits on the formation of policies. Some basic knowledge about the earth is a key to good future citizenship and effective living, and the knowledge must be instilled in our children on a national scale.

South Carolina Soil, Sun, and Surf: From the Mountains to the Sea.

Angela Rye and Cherlyn Anderson, Sandhills Middle School, 101 New Market Circle, Lexington, SC 29073 USA.

The Earth Science curriculum developed by Cherlyn Anderson and Angela Rye is based upon the integration of current technologies, hands on activities, field experiences, and interdisciplinary connections. Accommodating student learning styles and utilizing performance based assessments are also employed. The SCMAPS project is also an integral part of the curriculum. SCMAPS, developed by the State Department of Education and Clemson University, uses topographic maps, infrared lithographs, and satellite maps of 13 study sites in South Carolina. Each site's lessons include science, math, language arts, and SC History activities.

The year's agenda is based upon five thematic units. These units are:

Geologically Speaking—Students learn of the earth's geology through the exploration of South Carolina's mineral resources, field experiences to mining sites, utilization of commercial and teachermade videos and laser discs, and the Internet to study the earth's dynamic forces. The earth's geologic history is explored through paleontology.

Aviation Rocketry and the Final Frontier—Newton's Laws and the Bernoulli Principle are concepts learned through the construction of paper airplanes, model rockets, and, in math, tetrahedron kites. Students learn of the history of the space program and its future through NASA videos and the Internet. Living and working in space is investigated through the use of shuttle simulations and designing a moon base out of LEGOS. Students are also able to participate in a three day Space Camp Adventure in Huntsville, Alabama or attend a simulated shuttle mission at the Challenger Center in Columbia, South Carolina. Both teachers are NASA Honors' Teachers, having participated in NASA's NEWMAST summer workshops.

Weather Watchers—Through the use of a weather station and digital instruments, funded by a GTE GIFT grant, students participate in a year long study of meteorology. Students not only check daily weather information at school, but also state and nationwide via the Internet. Students complete portfolio assignments that include weather folklore. Culminating experiences include visiting the National Weather Service at Columbia Airport and observing how a television station acquires, analyzes, and reports weather data to the public.

Preserving Our Carolina Heritage—This interdisciplinary unit focuses on the state of our natural environment in South Carolina by studying the Congaree River, which is part of the Santee River watershed. The history and folklore of this area are studied, as well as political issues concerning the development of areas located along the Congaree. The Congaree Swamp, an International Biosphere Reserve, is also included in the study. Water and soil samples are collected on field study trips and later analyzed in class. The Internet and other technologies are used to gather research on worldwide environmental issues. Students also participate in an international telecommunications project to study air and water quality at project participants' community sites around the world.

Buccaneers, Bays, and Backwaters—Oceanography and estuary studies are completed in this interdisciplinary unit. Students are involved in current research of estuaries in our state through Estuary Net, the Baruch Marine Science Reserve, NOAA, as well as other oceanographic and marine science Internet sites. South Carolina's maritime history is studied through legends and folklore. A culminating experience is the sail aboard a tall masted ship into historic Winyah Bay.

Sandhills Middle School is located in a rural, socioeconomically depressed area of South Carolina. All technology and science equipment has been obtained through the concerted grant writing efforts of the seventh grade teachers. Through the combined efforts of team teaching, utilizing interdisciplinary units of instruction, and grant writing, Sandhills Middle School seventh grade students, regardless of ability or socioeconomic levels, have quality learning experiences.

Solutions.

Ellen Taylor, Shelley High School, 252 North 4300 East, Rigby, ID 83442 USA.

Currently there is a major trend in secondary schools that must be reversed before significant improvements in education will be seen. The trend is one of isolation. Students are isolated from other students. Students are isolated from teachers. Teachers are isolated from other teachers. Math is isolated from science and science is isolated from English. Earth science is isolated from chemistry and chemistry is isolated from biology. Schools are isolated from the business community. Secondary schools are isolated from middle schools and from post secondary schools. High schools are isolated from the college of education, and so on.

Shelley High School in Shelley, Idaho, has developed an educational approach that is intended to help reverse the trends toward isolation. The approach is called Solutions. In Solutions, actual problems from the community are identified and analyzed. The problems are analyzed to see if they will help reach our educational objectives, if they are safe, and to see if they appear to be solvable within our time restraints. Once a project is selected, a team of students sets out to solve the problem. Technical mentors from the business community, from government agencies and from post secondary institutions are identified to assist students with technical problems.

One community problem that closely fits the purposes of this conference involves the pollution in 962 of Idaho's streams and rivers. Students in the Solutions class are working with technicians from Idaho Fish and Game, The Dept. of Environmental Quality, Lockheed of Idaho, and Eastern Idaho Technical College to actually restore streams to a clean state. In order to accomplish this task, students are given an integrated foundation. This foundation consists of earth science, environmental science, chemistry, biology, math, communication skills, and computer technology. With this foundation, students are able to identify sources of pollution, develop intelligent plans for restoring water quality, and then remediate specific streams. An integrated curriculum is being developed that, when disseminated, will allow any teacher in Idaho to adopt the same approach.

Another need addressed in the Solutions concept deals with the idea of introducing prospective teachers to an integrated, problem solving approach to education. A number of aspiring teachers are working in the Solutions program in varying degrees. This paper is a joint effort between the lead Solutions teacher and a pre teacher just completing the teacher internship. The paper explained the Solutions model in detail and included results from the environmental restoration project as well as comparisons of academic achievements.

Geomythology

Joy Tanigawa, El Rancho High School, 6501 South Passons Blvd, Pico Rivera, CA 90660 USA.

FACTS

1. Find myths and legends from the Pacific Rim countries and islands that would be about earthquakes, volcanoes, tsunami, rain, floods, rainbow, plants and animals.
2. Share with students or have students share the knowledge of where they are coming from (Constructivist view) about their stories.
3. Share the scientific content. Integrate all the scientific content using the earth as the major theme, starting from the ideas of the legends and myths.
4. Students now know both views and a better knowledge of the earth to have them ready for the 21st century. Also many students will not let superstition drive their daily behavior, if it is harmful to them.
5. Give students simulations on past, present and future conditions. If any of the following could, would or did occur, how could they take care of themselves. What are some safety factors needed to survive in the environment?
6. Have them learn myths and legends from other Pacific Rim countries and see if their stories are similar or different. Conclude with the ideas of scientific content.

A Holistic Approach to Learning about the Earth, Utilizing the Outdoors, Computer, Lab and Classroom.

Yael Kali and Nir Orion, The Department of Science Teaching, Weizmann Institute of Science, Rehovot, ISRAEL 76100

Teaching about the earth as a system is a great challenge for teachers and curriculum developers. Each of the earth's sub-systems, the geosphere, hydrosphere, atmosphere and biosphere possess complex relationships between processes which eventually cause cycling of material within that sub-system. In order to comprehend each of these spheres, students are required to: a) understand the different processes which take place within that sphere, b) be acquainted with the starting and ending products of each of these processes, and c) understand that each end-product of one process can be a starting-product for another process. The understanding of this systematic nature of each sphere is a very difficult task for junior high-school and high-school students. Consequently, the understanding of relationships between these spheres requires an even higher level of knowledge integration with which teachers and curriculum developers have to deal.

Our poster presents a model which integrates two of the earth systems: the geosphere (including geological, chemical, and physical aspects), and the biosphere (including natural and artificial processes). The program deals with the difficulties of integrating their separate spheres of knowledge in the following ways: a) using the outdoor environment adjacent to the school for raising a real problem which serves as a learning organizer and requires knowledge of the different earth systems, b) teaching the different aspects of the earth by cooperation of science and geography teachers, c) using the outdoor environment as a natural laboratory for learning about the different systems of earth, and d) using the computer software KnoW3 (Svivot inc.) as a tool for integrating knowledge within each system and between the systems.

This poster presents an example of the implementation of this model in a junior high-school in central Israel. The school is situated near a small area of natural calcitic-sandstone hills in the middle of a very crowded municipal area. The future of these hills is still under debate by the authorities. The question of whether to preserve or develop the area is therefore used as the learning organizer for the program. This question is also the basis for a field trip to the area, where students are encouraged to ask different types of questions about their observations of the field site. The questions are then divided by the students into three categories: a) those concerned with the physical makeup of the area, b) those concerned with its biological properties, and c) those concerned with human influence in the area.

These activities are followed by a teaching stage dealing with different earth systems, which is taught by cooperative groups of science and geography teachers. Laboratory experiments and short field trips to the nearby hills are part of the program for each of the earth systems. The interrelationships within and between each system is emphasized by using the software KnoW3. This software enables students to organize their knowledge by building multimedia projects based on computerized concept maps.

Preliminary results from observations, interviews, and questionnaires show that:

a) The program succeeded in motivating the students to develop a holistic view of the earth.

b) Students improved their ability to think holistically about complicated systems other than the rock cycle.

c) Students' motivation for learning about science was increased.

Systematization in Teaching Method of Outdoor Education.

Hiroshi Shimono, National Institute for Educational Research, Shimomeguro 6-5-22, Meguro-ku Tokyo, 153, JAPAN

Today children in Japan are going to have little experience in nature. We have reviewed from various viewpoints how outdoor learning in science should be and showed the teaching material for it. In our research we have inspected the necessity of outdoor learning, pupils' recognition of environments, the pattern of outdoor learning, positioning the outdoor learning schedule, classification of the objects of pupils' observation, evaluation of the outdoor learning, and in-service teacher training. We introduced research on the status of pupils' recognition of their environments and examples of outdoor learning.

1) Status of pupils' recognition of natural environments

- Pupils change their objects of observation as follows:

1st priority—river, water, sediments on the riverside

2nd priority—grass and its flowers

3rd priority—existence and movements of objects and phenomena

4th priority—color, shape, size, quantity

- Pupils deepen their level of observation to research the change of objects, and by the influence of their questioning and previous experience.
- Pupils' activities are influenced by the character of place to observe, and the speech, behavior and advice of their friends and teachers.

2) Example of research based on topics: A natural environment was considered by investigating the pattern between topography and related air temperature. For several days students recorded temperatures at various times at points along a topographic profile of the region that included their school's valley and surrounding hills and plains. Patterns of temperatures by time of day were plotted on a graph that had the topography overlaid at the bottom. Students interpreted the data to show that the northern hill was influenced more strongly by artificial heat from buildings, and cooler air on the hills at noon might draw people to come there from the valley.

Capturing Student Interest by Integrating Literature and the Arts into Teaching the Earth System.

Lynda M. Samp, Dedham High School, 140 Whiting Avenue, Dedham, MA 02026

Many students who previously showed little interest in studying science are now turned on to learning about the Earth System due to the infusion of Earth beauty, Earth-inspired poetry, literature, arts and music. Weaving aesthetics into Earth System curricula can increase enthusiasm and learning of all students, regardless of age or ability.

Music is a great mechanism for evoking interest in science because virtually everyone loves music, people can express individuality through sharing their favorite music, and because infinite pieces are forever inspired by Earth and its systems. Musical works from a multitude of cultures have been inspired by the Earth and its subsystems, from classical to rhythm and blues, to heavy metal. There are several ways to use music related to the subject material in the classroom: as inspiration for a new unit, as background during a lab, as a special lesson on music interpretation, or simply for the students to play their own music for the class. Connecting the Earth System to science and nature-inspired music increases the relevancy of classroom learning.

Reading literature and writing poetry about the Earth comes naturally for some students who don't fit the traditional science scholar mold. Contests, such as the Massachusetts Science Poetry Contest, serve as strong motivators, and can be sponsored by outside groups such as universities or literary interests. School English departments are often very willing to involve themselves in crosscurriculum units with science classes. Along with poetry, writing science-theme essays and creative short stories interests many students. "I Survived the San Francisco Quake of 2002" is a tried and successful topic, where the student writes a scientifically accurate, yet creative narrative about how the disaster might affect them and society.

Creating original artworks, either those inspired by the beauty of the Earth System, or those using natural materials is another way to motivate the "right brain." Paleontology, for example, is a natural bridge between science and art. Starting with perhaps a dinosaur track, students can make casts, estimate animal length, posture, claw configuration and action through making drawings and models. These artworks in turn offer the instructor a means of alternative assessment.

Student interest in aesthetics, music, literature and art already exists, and it is important to avoid forcing people into doing something that they already love to do. Instead, provide opportunity through making time and materials available. Any time "lost" from traditional curriculum will be more than compensated for through increased interest and enthusiasm in your course.

Camp Planet Earth: An Earth Systems Science Summer Camp for Eighth Grade Minority Students.

John R. Giardino, Philip D. Rabinowitz, and Andrew Hajash, Jr., Texas A&M University, College Station TX 77843 USA. John D. Vitek, Oklahoma State University, Stillwater, OK 74078 USA

The new National Science Standards will require development of new curricula that emphasize integration of science. It is thought that this new approach to revitalizing science in K–12 will also have a positive impact on increasing the number of minority students pursuing careers in science. Diversifying science is necessary and challenging. During the last twenty-five years, numerous attempts have been made at the post-secondary level to recruit minorities to the earth sciences. Unfortunately, these programs have had limited success because they targeted potential students already in college. A problem with these types of recruitment programs is timing. Camp Planet Earth (CPE) was established to identify, excite, and track minority students through high school and college.

Each year fifty minority students participate in Camp Planet Earth (CPE), a four week earth systems science academy summer camp. Earth systems science serves as the locus for the camp. A detailed, field-based earth system science curriculum was developed. This curriculum integrates earth system science with the National Science Standards. During the camp, students learn to use the scientific method and earth system analysis combined with field research to develop and implement an earth system science-based science fair project. These projects are water related because water serves as the thread of inquiry to link biological, chemical, earth surface processes, and human interaction.

Classroom and field instruction are organized around the energy and mass pathways from the atmosphere to the watershed and through the river channel out of the drainage basin. This paradigm uses various disciplines such as geomorphology, hydrology, meteorology, chemistry, biology, and landscape ecology to study and understand inputs, outputs, stores, pathways, thresholds, and system equilibrium.

The final two weeks of CPE is intensive field work where students conduct mapping and data collection. Students were instructed in field methods and taken to field sites to practice techniques. The students were divided into research teams and were encouraged and helped to identify a scientific problem, set research objectives, design the sampling method, and collect and analyze the data. The data serve as the basis for a science fair project that is completed before the student leaves CPE. Participation in a science fair occurs during the following school year. Participation and progress in science fairs are monitored.

Contact with each student is maintained via a newsletter, and each student's progress throughout high school is tracked. Continual contact is an opportunity to provide support and encouragement to each student to attend college and major in earth systems science.

Earth Sciences and Environment: An Introduction to Earth as a Living Planet.

J. Lillo Beviá, University of Vigo, Galicia, Av. Buenos Aires 26–28, Pontevedra 36002, SPAIN

The recent reform of the curriculum of Secondary Education in Spain affects pupils between 12 and 18 years. For pupils of 18 years, the matter of Earth Sciences and Environment is envisaged as an option for the biosanitary and scientific-technological branches. The pupils should be examined on such material as a previous step to University. Each autonomous community develops the curriculum of these subjects adapting it to the own environmental problems of their communities.

In Galicia (Northwest of Spain), the development of the curriculum and the access tests to the University affects the Coruña, Vigo and Santiago of Compostela universities equally. In this community the curricular development has been focused as an Introduction to the Earth as a Living Planet, integrating the systems of Earth and surveying problems derived from human impact over time.

We have developed two alternative approaches that each High School can adapt to their local or regional peculiarities. Ability to do scientific work will be a constant in either of the approaches. Approach "A" is centered in systems theory, and in each system are integrated the own concepts of the system with their derivatives from the resources, risks and impacts, and the abilities of the scientific work. Approach "B" continues the topics elaborated for all Spain, and sequentially studies the characteristics of the scientific work, the Earth systems, risks, impacts and problems derived from human impact on the Earth, including the perspective of sustainable development and environmental education.

A characteristic common to both approaches "A" and "B" is that envisaging in each thematic unit the relationship between conceptual, procedural and attitudinal contents, with priority givento the procedural contents. These types of contents intend that pupils be able to master basic abilities such as: to select and extract scientific information from documents, to employ basic laboratory and field techniques, to know how to use and interpret cartographic techniques, to elaborate reports and communicate the results of an investigation, all this being centered in the study of a concrete environmental problem as a work project. The evaluation of the curriculum is established according to the environmental regional or global problems interpretation by the pupils.

Session Summaries IIB: Teaching at the College and University Level, and IID: Innovative Approaches to Instruction about the Earth.

This is a combined summary prepared by Nir Orion from discussion leaders' notes provided by Orion, Yael Kali, Donald Oakley, Lynda Samp, and Michael Walsh.

As we learned from many of the presentations, teaching and learning in the earth systems framework is an educational challenge. The following subjects were raised throughout the presentations as key factors in order to fulfill the educational challenge of the earth systems approach:

1. The main constraints to implementation of earth systems programs are teachers' and students difficulties in teaching and learning subjects in an integrative manner. Therefore, we should focus on intensive study of the factors which involve in effective integrative or multi-disciplinary learning and teaching.
2. The outdoors was clearly found to be a very common learning environment for Earth systems education. More study and curriculum development should be invested in this area in order to use this important learning environment more effectively.
3. The earth systems approach can and should be implemented along all the range, from K–12. In order to do it effectively we should pay attention not only to the horizontal scope (the multidisciplinary characteristic), but also to the vertical domain, namely the development of this subject from K–12. This should be followed by curriculum materials development which should be preceded by pre-development research and followed by a formative evaluation study.
4. The limiting factor for the implementation of Geosciences education in general and the earth systems approach in particular are the science teachers. Science teachers all over the world have insufficient earth science knowledge background. Therefore, the introduction of Earth system science education into schools is highly depended on our ability to develop and implement effective in-service training programs for the teachers from K–12.

Theme III: Public Information, Research and Innovation

Rosanne Fortner and Dan Jax, Coordinators

Session IIIA: Research and Evaluation Studies of Instructional Innovations

Alfredo Bezzi and Roger Trend, Moderators

As one presenter noted, much of the research on educational change never results in differences in classrooms. These posters, however, offered exciting and relevant information from research in seven countries that can inform practice in our Earth systems teaching. For example, state and national curriculum reform efforts have a variety of effects on geoscience education, from loss of autonomy by teachers to opportunities for including environmental awareness in the science curriculum. Student misconceptions about Earth processes and events are being revealed by new assessment techniques such as concept mapping, and the same techniques can be used to help students structure their information into meaningful learning. Research using population modeling for the profession, abduction inquiry as a learning tool, and perception of geoscience by students and teachers all offered ideas for improvement of Earth systems/ Earth science education.

Implementation and Assessment of Remote Sensing Concepts in the Classroom.

Susan Oliver, Owasso Eighth Grade Center, 7714 N. 126 E. Avenue, Owasso, OK 74055 USA.

SCOPE AND METHOD OF STUDY:

Activities and materials were gathered and developed to produce a unit of study in remote sensing. The unit was implemented by the author through her science classes and presented to 116 eighth grade participants. An overview of the remote sensing unit of study was presented and assessed.

FINDINGS AND CONCLUSIONS:

A pretest revealed misconceptions and indicated a lack of knowledge associated with remote sensing ideas and concepts. The activities and materials were significant in the overall success of the unit. Authentic assessments including portfolios, session summaries, concept maps, and individual conferences were utilized along with a written test. The results of this study indicated that remote sensing concepts are viable teaching tools which offer students a valuable, interdisciplinary learning experience. Junior high students showed they were capable of interpreting remotely sensed data and demonstrated proficiency in the use and understanding of remote sensing concepts.

Special credit was extended to Dr. Steven Marks at Oklahoma State University, who used landsat images to make a mosaic of Oklahoma.

Earth Sciences Education + Environmental Education = Earth Systems Education.

Nir Orion, Science Teaching Department, The Weizmann Institute of Science, Rehovot, ISRAEL 76100

[Dr. Orion provided this special overview as background for the three abstracts that follow.]

Today, more then ever, there is a worldwide recognition that living in peace with our environment is more than just a slogan, it is an existential need. It is also agreed that understanding of each of the earth's sub-systems and the environment as a whole is indispensable in order to live in peace with the environment. This understanding is actually what science all about. There are many ways of approaching environmental education. It is suggested that life on earth should be the starting point and the end product of environmental education. I believe that the main purpose of environmental education is to bring students to understand the interrelations between life and the physical environment. Our future citizens should understand that life influences and is influenced by the natural environment. The natural environment is a system of interacting natural subsystems, which each one influences the other ones. They should understand that any manipulation in one part of this complex system might cause a chain reaction that could come back as a boomerang effect. The translation of these noble ideas to a practical educational plan is a very challenging task. Our view is that real understanding of the environment is based on understanding of its scientific principles and processes. The societal and technological aspects of this area should provide the relevant context for the study of the scientific concepts.

Environmental education should be an integral and indispensable part of the science curricula from K-12. Moreover, its critical necessity for our society, its relevancy to students' daily life, and its multidisciplinary nature demand that environmental education should have an honored central place in the science curricula. The multi-disciplinary characteristic of environmental studies, their relevant importance and educational potential inevitably suggest that this subject should be also included with association to all the scientific disciplines. One way to introduce environmental topics to the science curricula is by using relevant environmental topics as a motivation to learn scientific concepts, and in higher learning levels, one can use previous scientific knowledge and principles in dealing with earth systems. Their should be clear definitions in relation to the knowledge and principles of educational literacy as we have in all the scientific disciplines. The environmental content should focus on two main domains: a) Case studies of environmental issues (the symptoms), and b) the development of an environmental insight.

WHAT DOES "ENVIRONMENT" MEAN?

Environment is a very broad term. It ranges from the natural environment through the man-made environment, the home environment and the personal environment. However, the most common consideration of the "environment" is in relation to pollution of the environment or in the positive side of the coin—the quality of the environment. Also, these two parallel terms have a large range of aspects, from worldwide issues such as global warming, to regional issues such as water pollution, to more local issues like conservation of specific localities; from economical and technological derived debates such as alternative energy sources, to values such as the development of roots towards the homeland and to more moral decisions such as protection of endangered species. In principle and also in practice, one can relate almost everything under the *environment* title.

In the scientific community there are two main schools of looking at environmental studies. Both approaches look over the interrelationships between man and the physical environment, however they differ by their perspectives. One school is more concerned with the understanding of the physical environment: studying the five interacting Earth subsystems or spheres—atmosphere, biosphere, cryosphere (ice), hydrosphere and lithosphere. The other school is more concerned with the environmental hazards from the human life perspective. This approach gives more attention to the interrelation between energy and environment, the exploitation of our limited energy resources, and its effects on the environment. The human society, for this approach, is an integral part of the earth system. Technology has a dual part in the societal-environmental interaction. On the one hand, the technological revolution and the over-using of energy resources dramatically increased the damage of some aspects of the environment, but on the other hand, new technologies can help in limiting environmental hazards and in providing alternative energy resources.

OUR PERCEPTION OF ENVIRONMENTAL EDUCATION

As a result of the multi-disciplinary characteristic of the "environment," namely social, technological and scientific aspects, different educators give different interpretations and focus to the term ENVIRONMENT and consequently to the term environmental education. The central topic of the Israeli educational system during the year 1993–94 has been the environment. Based on my observations throughout this year, it seems that many environmental programs did not go far beyond topics such as cleaning our living area, recycling and protection of the nature. All these topics are no doubt very important, however, environmental education, in my perception, should deal with a deeper consideration. In order to develop environmentally literate citizens, it is not enough to focus on the affective domains of the environment. The main task of a science educator is to translate the scientific ideas into a practical educational plan. In relation to the two scientific approaches described above I have no doubt that the human perspective should be the focus of environmental education. According to the relevancy of environmental issues to students' daily life and the main purpose of the educational system which is to educate, life on earth should be the starting point and the end product of environmental education. However, as we can see from many existing environmental oriented programs, any attempt to develop environmental literate students without giving them, at least, general acquaintance with and understanding of the physical environment could never reach far beyond the level of recycling and cleaning of the school yard. This acquaintance and understanding means study about the earth systems. Each subsystem for its own, the interrelationships between them and mainly their interrelationships with man. The key role for real understanding of the physical environment is the understanding of the basic scientific principles and processes which are related to earth systems. Thus, the starting point and the end product of environmental education should be the man, but in the middle, the key for achieving any basic environmental insight involves the study of the scientific characteristics of all the earth systems including the physical environment.

THE INTEGRATION OF EARTH SYSTEMS WITHIN SCIENCE EDUCATION

The suggestion that development of environmental insight is based on scientific literacy means that studying our earth systems should be an integral and indispensable part of the science curricula from K–12. In an era of a revolution in science education all over the world, which starts to move towards "Science for all" approach, earth systems education should take a central place in the science curricula from K–12. This demand is based equally on the critical necessity of environmentally literate citizens for our society and the educational potential of this subject, namely its relevancy to students' daily life and its multi-disciplinary nature. In order to give the noble ideas a real meaning and authority, there should be a definition of what is an environmental literacy. This should be done by a committee of environmental scientists and science educators. In Israel we use two ways of introducing environmental-earth systems topics into the science curricula. One approach is to use relevant environmental topics as a motivator vehicle to learn scientific concepts. For example, the topic of global warming, which is mentioned quite often in the media, could serve as a motivator for the study of chemical and/or biological processes which are involved in this phenomenon. Earthquakes, for example, could serve as an advance organizer of learning about the earth crust and about change as a physical phenomenon. On the other hand, one can use previous scientific knowledge and principles in dealing with environmental topics. For example, the study of the carbon cycle should be based on prerequisites of basic concepts in chemistry, biology and earth sciences.

We find that both approaches are useful and can be implemented successfully in relation to a specific age and program.

- The environmental-earth systems content should be included in the science curricula
- The environmental-earth systems content should focus on two main domains:—Case studies of environmental issues (the symptoms).—The development of environmental insight through studying of systems.

As mentioned above, environmental issues can serve both as a vehicle for learning scientific concepts and for organizing and implementing previous scientific knowledge. Environmental case studies should be selected in relation to the relevancy of the phenomenon to the students' daily life experiences and its importance to the future of the humankind. It is suggested to classify such case studies to three levels:

—The local level

—The national level

—The global level.

Local case studies are varied from one locality to another. For example, air pollution is a very relevant topic for students who live in the Haifa gulf region, while floods are more relevant to other localities. An example for one of the most important environmental subject in the Israeli national level is the hydrological system. The greenhouse effect and the global warming debate is an example of global topics. Through such case studies, students might understand the cause of some specific hazards and hopefully, what should be done to recover or prevent them. However, for me, the main purpose of environmental education is the development of environmental insight. This insight is based on the understanding the system-cyclical mechanisms of our planet. The common factor for all environmental hazards that humanity faces is that they are derived from people's unawareness of the fact that society is a part of the environment which is composed of several interrelated subsystems. They are not aware that any manipulation in one part of this complex system might cause a chain reaction that might come back as a boomerang effect. In order to develop this insight I would recommend focusing on geochemical and biogeochemical systems such as: rock cycle, water cycle, food chain, carbon cycle, oxygen cycle and energy cycles. However, the studying of such systems should not be sterilized and should be conducted in the context of its influence on man's daily life.

THE EDUCATIONAL CHALLENGE

The environmental-earth systems education approach which is presented above is quite a challenging scheme. It involves the development of cross-curricular and cross-age programs. It involves interdisciplinary subjects and most of all it involves the teaching and learning about quite complex interrelated systems and the development of system-cyclic thinking. Thus, science education must find the most appropriate teaching and learning strategies for achieving these goals. Since the resources of science education, namely teaching hours, are very limited, an additional important challenge of science education will be to find the minimal scientific background needed for the development of environmental literacy. In other words, they will have to find a way for not being too shallow in one hand, and not to go too deep and staying in the natural systems level, without reaching the human perspective of the environment.

In order to fulfill the educational challenge we have taken the following actions:

1. Together with environmental and earth scientists and science educators we try to define what is educational literacy or environmental insight.
2. We try to convince educators (with the scientific support) that the earth system should serve as framework for "Science for all" programs from K–12.
3. Mapping of the different programs for science majors in the high school, in relation to earth systems subjects. The purpose of this survey is to point out those parts of the curricula which can be taught in an environmental context.
4. An intensive study which focuses on students' cognitive abilities in perceptions of cyclic multi-dimensional systems.
5. An intensive study which focuses on learning and teaching integrative or multi-disciplinary. It is my suggestion that the main constraints to implementation of environmental programs are due to both teachers' and students' difficulties in teaching and learning subjects in an integrative manner. Thus, the study will have two domains:
    a) A study will focus on students' abilities and strategies in integration of concepts between different disciplines and within a single discipline. The main object of this study is to suggest models and strategies to organize and to teach integrative subjects, and
    b) A study which will look for appropriate strategies for the implementation of multi-disciplinary programs and subjects.
6. The development of curriculum materials for the science curricula from K–12.
7. A key role for success in the above steps is a close relationship with the professional science community and their strong support. According to the multi-disciplinary nature of environmental studies, there is no single scientist who can cover all the aspects of this large area. Therefore, one of the most important conditions for the development of scientifically sound curriculum materials is a strong scientific backing of a group of scientists who are specialized in different aspects of the earth sciences and environment studies.
8. In-service training for teachers. The implementation of the learning materials is involved with massive in-service training (INSET) programs for the teachers who have to teach these new materials. Since for many of them both the subject matter and the integrative approach are quite novel, the INSET programs should be focus on both subject matter enrichment and the development of the appropriate teaching strategies for cross curricular teaching.

The locating of appropriate niches for the infusion of environmental or earth systems oriented units in the curricula, the development of appropriate learning and teaching strategies, the development of appropriate learning/teaching materials, a massive INSET programs and a strong support of professional scientists are already starting to have their positive influence on the quality and quantity of the earth systems teaching and learning within the Israeli educational system.

Understanding the Water Cycle in the Context of the Earth System.

Orit Ben-Zvi Asarraf and Nir Orion, The Science Teaching Department, Weizmann Institute of Science, Rehovot, ISRAEL 76100

In the Israeli school system, the "water cycle" is one of the most common themes among science curricula. This reflects the fact that it is a multi-disciplinary topic which includes elements from all the sciences.

However, students rarely receive an integrated picture of this cycle, because its various elements are farmed out amongst the different scientific disciplines. For example, in the biology program, students study the role of water in human physiology.

Research has shown that students who do not receive a coherent picture of the water cycle usually possess many misconceptions about it. A better approach starts with the water cycle as an integrated earth system, similar to the rock cycle. Thus, neglected elements in the cycle, such as the role of groundwater, should be added to the more commonly presented evaporation and condensation processes to present a complete picture of the cycle. Further, changes in water state must be connected to the general earth system, rather than being taught as disassociated physical and chemical processes.

The junior high school program "The Blue Planet" addresses these criticisms by:

1. presenting a coherent depiction of the various processes (chemical, physical, geological and biological) at each stage of the water cycle.
2. relating the water cycle to the various parts of the earth system (lithosphere, atmosphere....).
3. presenting the water cycle in a Science, Technology and Society (STS) format. This provides a wider scope of investigation, from previous curricula which had a narrow pure scientific basis. During the program, students pursue independent research in which they demonstrate their knowledge of the STS elements of their projects.
4. using constructivist methods to alter the students' misconceptions of the water cycle. This is needed because the fragmented picture that students usually receive of the water cycle contributes to their misconceptions.
5. using the computer to access the global data base so that students understand that the water cycle is a world wide phenomenon.

"The Blue Planet" was taught during the 1996/97 academic year to three 8th grade classes of Israeli school students. At the same time, research was done accessing the students changing understanding of the concepts presented in the program.

Earth Science Approach to Teach Global Carbon Cycle in High School Level.

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The following work presents a module which deals with the global carbon cycle, as well as the research conducted prior to its development. Traditionally the global carbon cycle is mentioned and taught in high school only in relation to the biology or chemistry curricula. Our program was designed for Israeli high school students "majoring" in earth sciences and it is a first trial to teach the carbon cycle in the context of all earth systems.

The global carbon cycle was chosen because it allowed us to illustrate various interactions among different earth systems. In addition, it has major relevance to the current environmental crisis (for example the increasing "greenhouse effect"). Finally, it is illustrative of the way science operates, presenting as it does, a problem that is dependent on all of the scientific fields.

Three basic principles guided the development of this module:

- Public awareness about the influence of human activities on natural systems.
- The recognition that learning is a process of adding to existing cognitive constructs (constructivism).
- Utilizing computers (including the Internet) and the media to expand the available data base for student activities.

The goals of this work are:

- to define students' prior knowledge about global atmospheric change, and the global carbon cycle.
- to utilize the global carbon cycle as a model for illustrating interactions among the various earth systems.
- to develop basic skills for future learning in science. Thus, the module includes a wide variety of exercises, many of them based on self directed activities such as reading research articles.
- to develop instructional methods that will aid teachers in developing systematic patterns of thinking in their students.

Preliminary findings of our study identified several misconceptions for example: Stratospheric ozone layer depletion is one of the causes for the enhanced greenhouse effect; ozone is a helpful gas in all layers of the atmosphere including the Stratosphere; enhanced greenhouse effect causes more people to get skin cancer. Following the implementation it was found that the students' motivation for this curriculum increased substantially during the year and some of their misconceptions about this topic were eliminated. For example, the students came to understand that although man is a large factor in the global carbon cycle, his effect has only been pronounced in the last instant of geologic time. Finally, because of the global nature of this program, they were able to distinguish among different environmental problems that affected the different earth systems.

Incorporating Environmental Aspects of Earthquakes within the High School Earth Science Curriculum.

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The purpose of this research was to design a program that increases the environmental aspect of the high school earth sciences curriculum. The specific focus of this program was earthquakes, their geology, physics, economic influences, and social costs.

Along with its development this curriculum was tested to determine the effectiveness of the curriculum material and learning strategies. Finally, the potential of multimedia authoring, as a learning tool, was examined among students using the software ASTOUND. The subjects of this study consisted of 32 students divided among two Grade 12 high school classes.

The curriculum has three consecutive phases:

1. Introductory phase: Students were provided with a basic background into earthquakes. Towards this end, the following curriculum materials were developed:

- A laboratory manual containing earthquake related experiments.
- A field guide presenting students with geological and historical evidence of earthquakes in Israel. This guide was designed in order to prepare students for a two day field trip to the Dead Sea and The Galil.
- An example of a multimedia presentation about earthquakes.

2. Independent study projects: In this stage, students did in-depth study on a selected topic related to earthquakes.
3. Student designed multimedia projects: In this stage, students presented the results of their independent research using the multimedia authoring tool ASTOUND.

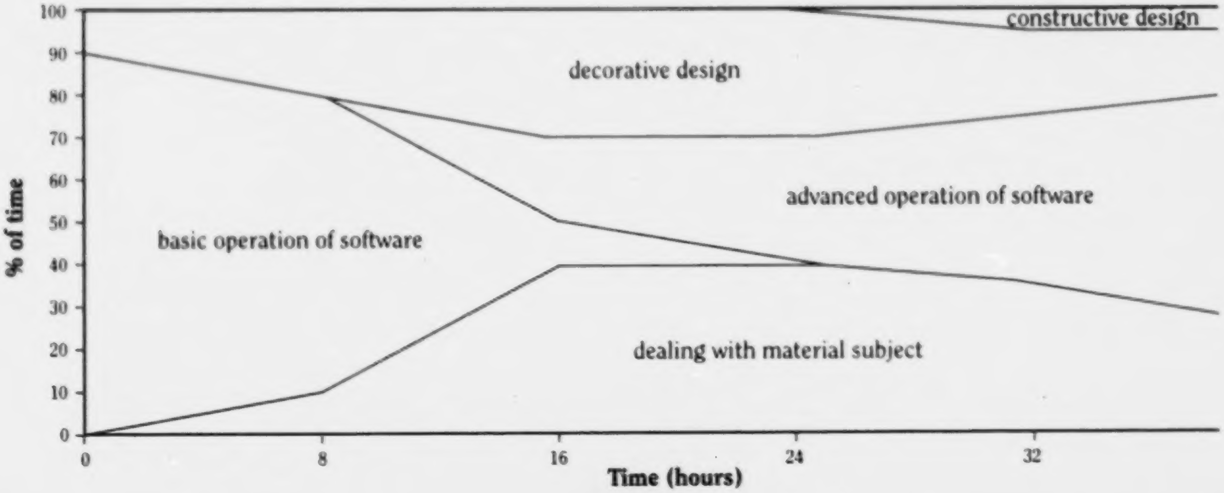
The research consisted of a Pre-development phase; curriculum design phase; implementation and evaluation. The research tools included questionnaires, interviews, classroom observations, concept mapping, and in depth analysis of multimedia presentations.

The general result shows that an integrated program consisting of laboratory exercises, field trips and independent study project can lead to meaningful learning. This is reflected by the fact that there was an overall increase in student understanding about earthquakes. However, at the same time, the two subject groups do show a major difference, according to the quality of their presentations. The class that produced better independent study projects showed a deeper appreciation of the significance of earthquakes to the human environment. They also developed a greater understanding of interdisciplinary science.

These results suggest that this curriculum serves as good general model for implementing other types of environmental issues in earth science education.

[See figure below]

Although the students enjoyed using the multimedia program, there was no evidence to support the assumption that it contributes to knowledge acquisition. In fact, much of the time spent on multimedia authoring was merely decorative, which took time away from meaningful learning. Thus, it is suggested that in order to take advantage of the potential of this tool, one must first teach the student proper presentation design.



Changes in the Earth-Sciences Classroom Influenced by Educational Research.

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INTRODUCTION

The main aim of this paper was to discuss the relationships between the suggestions provided for educational research in Earth-sciences and their reflections in school science classrooms. We claim that educational research in Science Education namely in Earth Sciences is of no value if it is not strongly reflected in practices at the classroom. Nevertheless the gap between the results achieved by the research teams and the strategies and activities still used by science school teachers is well known, i.e. the dialogue between academic researchers and practitioners has not been developed enough (Kempa 1991). We think that one of the obstacles causing this unpleasant situation is related to the lack of teachers' own participation in the activities carried out in the research teams. It seems that the picture concerned with the real situation is quite well defined: on one hand research projects are developed *for* science teachers rather than *with* teachers, and on the other hand there is a lack of inservice training programs for helping teachers rethink their practices towards innovative ones. For changing this procedure a set of attempts have been developed during the last few years in Portugal. The discussion of the context of this issue was the subject throughout this paper.

SHAPING THE PROBLEMS

There is a political preoccupation with, and policy emphasis on, education in general and science education in particular all over the World (Laws 1996). If there is this common view about the relevance of achieving meaningful science concepts, it is not easy to understand, at least in a first glance, why students decrease progressively their enjoyment for science as they grow. This means that one finds dissatisfaction among

- teachers about the effectiveness of their teaching.
- curriculum makers concerned with the gap between the aims pointed out and the results achieved by the students.

Understanding of Geological Time among Children, Teachers and Student Teachers.

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The understanding of many Earth Science processes and events is strongly dependent on a grasp of geological time. This key concept lies at the very heart of geology, yet very few educational researchers have investigated how children and others conceive it. The proposition is made that UK society has no shared understanding of "deep time," unlike equivalent core concepts in other disciplines such as "life" in biology, "light years" in astronomy and "historical time" in history. There is a vicious cycle of shared ignorance and misconception, with little evidence that it can be interrupted easily. Even when geological phenomena appear in popular culture, such as Spielberg's 'Jurassic Park' film, there is no evidence that understanding of deep time is enhanced.

It is proposed that this state of collective emptiness in relation to deep time provides a barrier to understanding of other geological concepts, including events in the geological history of planet Earth. It is postulated that student teachers, teachers and parents are insecure in their grasp of deep time so they are unable to devise effective learning activities. When a child produces a fossil or asks about dinosaurs, such adults lack the knowledge and understanding needed to respond in powerful ways, which might include reference to the time context. This core concept is dismissed with phrases such as "millions of years ago" or "a long time ago" and attention is shifted, perhaps, to the specimen's physical attributes or the dinosaur's habitat.

In their teaching of Earth history, many UK teachers are unable to capitalise on any existing understanding and expertise. This is in marked contrast to the imaginative and informed approaches they use when teaching children about historical events. For example, many teachers are highly creative in their use of historical evidence such as artifacts, pictures, documents and recorded interviews with old people. They can locate historical events in chronological sequence and can reinforce the continuity of historical time through reference to extant phenomena. When faced with an historical event or artifact they can provide children with powerful lines of enquiry.

This paper presented the results of empirical research into the knowledge and understanding of geological time by a range of children, teachers and student teachers. In all cases many different but familiar geological events, phenomena and objects provided the framework for a range of test items focusing on deep time. A range of research instruments was used, including structured and open interviews, questionnaires, concept mapping, question generation, drawing and word association. Key areas of misconception are identified for each category of child and adult. In particular, misconceptions which appear to be persistent are identified and possible lines of intervention are suggested.

Although the English/Welsh National Curriculum in Science and in Geography is relevant to only a proportion of the respondents, such content is related to the core concept of deep time. A longitudinal study will be required in order to evaluate any influence of the National Curriculum on UK society's understanding of deep time.

Developing an Earth Science Inquiry Learning Model Based upon the Characteristics of Earth Science.

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Various research methods have been used in science depending on the context of science research. This implies that various inquiry learning models, instead of just one, should be developed based upon the characteristics of each content area for more effective science learning and better understanding of the nature of science

The context of earth science research is quite different from that of other areas of natural science in terms of its time-, space-, accessibility-, complexity-, and operationability- dimensions. The purpose of earth science research is twofold: historical and causal. One of the characteristic inferences in earth science is abduction which includes analogical reasoning and eliminative induction.

Abductive inquiry learning model was developed and described in this paper. The model emphasizes the search for possible processes of the past which form the present earth, and selecting the most probable process based upon the limitations of the phenomena observed. The application of the selected process to the real world is also stressed in the model. The possibility and effectiveness of the new model should be tested in the near future.

Teaching the Evolution of the Atmosphere and Oceans.

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The Science National Curriculum in England and Wales, which for the first time brought Earth science content into the compulsory school curriculum for ages 5 to 16, has undergone several major revisions in its short life from 1989. There has been sustained pressure from other major sciences to reduce this Earth science content at every stage of these revisions, but there are still small but significant sub sections entitled 'geological changes' in the science curriculum for both 11 to 14 and 14 to 16 year olds, incorporated within the chemistry section.

However there is an aspect of Earth science in the latest (1995) version that features in a rather curious way outside the geological changes section, and appears to be a remnant of the meteorology section of the previous (1991) version which was otherwise cut out entirely. Why this statement survived a revision designed to cut down the total content was not made clear:

'Pupils must be taught how the atmosphere and oceans evolved to their present compositions.'

This statement is placed in the chemistry section, just before the geological changes sub section, within a sub section entitled 'changes to the atmosphere,' along with a second statement: '.....how the carbon cycle helps to maintain atmospheric composition,' which perhaps indicates why the topic is considered important for the science curriculum for 14 to 16 year olds. Yet most chemistry teachers, let alone other science teachers, have little knowledge of the present state of scientific understanding of the origin and evolution of our atmosphere and oceans. Indeed a review of existing school science texts indicates the topic is largely ignored, or treated very cursorily, while no accessible texts appear to review the topic as a whole.

For this reason an overview of current understanding was attempted to use with science teachers in in-service programmes. This was accompanied by suggested learning objectives for pupils, and possible teaching strategies. The materials have been used several times during in-service presentations, but are regarded as still under development both in terms of the extent and accuracy of the scientific 'story lines' and in terms of a reasonable interpretation of these for teaching and learning with 14–16 year olds.

The poster presentation set out the 'story lines,' the proposed learning objectives and teaching strategies, and invited comment and advice from other participants.

What is This Thing Called Geoscience? The Perspectives of Some Geography Students and Their Instructor.

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Students' perceptions of science are considered by science educators a fruitful area of research for improving teaching and learning. The rationale to acknowledge the importance of this kind of studies includes: (1) the need for science education to improve scientific literacy and hence public understanding of science to appropriately prepare informed citizens who can fully participate in a modern democracy; (2) the need to elicit the images of science that students are likely to hold when they enter the science classroom.

The main aims of this study were to outline the image of some geological disciplines constructed by undergraduate students, and to verify whether the teaching of Geology could affect the construction of such an image. The subjects of this research were eight first year undergraduates of the Geography degree course and their Geology instructor.

Researchers in this domain generally carried out their studies directly interviewing people, or indirectly analysing textbooks, newspapers, lessons, television programs, written drafts, and drawings. In this investigation the author used the repertory grid technique, the tool envisaged by George Kelly to elicit people's personal constructs according to his theoretical framework known as "Personal Construct Psychology." Kelly's theory is based on the assumption that individuals psychologically work in accord with their attempts to give their surrounding world a meaning, through hypotheses which are either refused or verified as a result of subsequent experiences. The basic units of these hypotheses are the 'personal constructs' which offer an idiosyncratic model of reality for each individual.

The elicitation of constructs took place at the beginning and at the end of the academic year. Principal components analysis was used to determine teacher and students' constructs with the most important epistemological value, i.e. the constructs that mostly affect students' perception and interpretation of the geosciences.

Students' and teacher's constructions were grouped in five categories: 1. Objects, areas and techniques of investigation. 2. Nature of science. 3. Application of science and its professional aspects. 4. Affective aspects. 5. Characteristics of the courses. The findings indicated that some stereotyped images of science appear with a characteristic antithesis between Physics, considered objective and rigorous, and the Geosciences, seen as subjective and approximate. This continued viewing Geosciences from the perspective of Physics emerges in particular from data illustrated by the principal component analysis where many of the constructs matching with this commonplace image seem to be a persistent keystone of teacher's and students' epistemologies.

In relation to cultural and societal aspects inherent with geosciences, the data show that professional aspects connected with the application of geoscience to everyday problems decreased at the end of the academic year and little concern to societal issues emerged as a significant conceptual dimension. These results seem to indicate that simply teaching Geology doesn't change students' images of geosciences. Such a conceptual change must come from within students' cognition and, therefore, the awareness of students' beliefs should be the starting point to allow for this cognitive reconstruction.

Growing Populations of Geoscientists.

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The British Geological Survey has offered a life-time's career to geoscientists for over 160 years. In the past six years, it has taken corporate action to develop the skills of its scientists to meet its changing business needs, particularly because of the increase in short-term contract work over the central government funded work (Penn 1996, 625–632).

Survey staff (currently totalling over 800 men and women) can be classified in populations of distinct professional groupings, such as field geologists, hydrocarbons geologists, hydrogeologists, or seismologists, which embrace such a diversity of geoscience skills that the phrase 'one-stop-shop' has been used to describe the organisation. These geoscientists are supported in their work by populations of information technologists, scientific support staff and others.

Plots of age versus year for each of these professional populations show distinct patterns depending on rates of recruitment, deployment and mortality (generally retirement). Broadly speaking, J-shaped curves characterise new groups with a high, youthful intake such as Information Technologists, and groups with a high staff turn over such as Scientific Support Staff. Long established groups, such as Field Geologists and their supporting Cartographers, show unimodal agedistributions, whereas groups which have not recruited regularly have a high proportion of aging and older staff and they face natural extinction.

Maintenance of such populations gives a longer term stability to the staff population of BGS as a whole than would be the case if staff were hired and fired to meet short term contracts. They give time to allow skills to be nurtured, individuals to be fully professionally developed and staff to be retrained if it is thought populations are imbalanced. Thus the groups are defined and individuals grown from youth along the lines set down by internal training guides geared to standards of professional accreditation set by outside bodies such as the Geological Society of London. More mature staff follow similarly governed paths of Continuous Professional Development.

The scale, rate of development, and the balance between professional populations is determined by the organisation's business needs. Current populations have hitherto enjoyed a low rate of mortality and retain characteristics of previous bursts of growth. Thus some populations show cyclically recurring age-frequency peaks indicative of cyclical recruitment on varying scales, depending on the organisation's changing business interests over the years. It is thought that a future goal of population growth will be to ensure more uniform growth by the development of staff skills through retraining allowing redeployment.

Staff development, including training and retraining to ensure a viable ecosystem of balanced populations, is guided by the organisation's adherence to an external, UK national standard of training and devlopment. This, the *Investors in People* standard, has its origins and current main success in the private sector where it ensures that training is related to business need. It is not easy to achieve the equilibrium populations, and considerable managerial skill by directors and senior management is required. Given the wide range of geoscientific (and other) skills in BGS, it is felt that such population modelling within BGS may be taken as a general approach to growing populations of geoscientists (and other scientists) within communities such as companies or countries where resources are finite.

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Earth Science Teaching: An Approximation to a Comparative Study in Some Latin Countries.

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During the IX Symposium on Geology Teaching (Spain, 1996) a group of professionals from latin countries interested in geoscience education was formed. The first task was to make a comparative study of their educational systems and the way Earth Science is taught and the teachers who are in charge of the courses. The results will lead to a second step aimed to design one or two research lines to generate some discussion about Earth Science teaching in the context of these countries. This paper presents some results from the first task of this group about ES teaching in these countries.

The curriculum is national with some regional participation, except from Brazil. Argentina, Brazil and Venezuela are having a reform process financed by the World Bank in order to have a Basic National Content Curriculum that will be finally designed in every state. This approach is very strong especially in Basic Education (primary plus lower part of secondary school).

Except in Brazil, these countries use the "center to peripheria" curriculum model. The rationale of this model lays on well prepared teachers using the "right approach" to teach, but the real situation is that there is a big gap between the planned, the implemented and the achieved curriculum. Under these conditions there is a need for better university teachers' courses and for a strong in-service program. In Basic School the tendency is to have a "fragment content" Earth Science curriculum rather than integrated courses. Earth Science can be found in Natural Science and Social Sciences subjects. There is a diversity of ES courses at Secondary School. In Spain, Italy and Venezuela there is one year ES course, although at different ages. Earth and Environmental Sciences in Spain is an optional course. In Italy there is an experimental ES course at upper secondary school and there is a compulsory ES subject in Venezuela. In Argentina ES contents are found in natural science subjects and in geography subjects in Brazil and for Cuba these contents are in Biology and Geography.

The approach of planned ES courses tends to be integrated within the sciences that aim to study our planet and these curriculum have a very strong emphasis on environmental situations.

The majority of teachers lack training in ES, especially basic school teachers. In Brazil and Italy the training of basic school teachers is done at secondary school level although the tendency is to progressively demand a university degree. At secondary school, teachers for these courses are trained as geologists or other natural science specialist in Argentina, Spain and Italy. In Venezuela there are ES teachers although they are not the majority of teachers in charge of this subject. In Brazil, because ES contents are incorporated within geography subjects, teachers are geographers, and in Cuba they are Biologist or Geographers.

From this panorama it can be said that there is a mixed up situation where it is not clear what is meant for Earth Science and Geography. There is a need to clarify this epistemological issue within the reform process that is under way in the majority of these countries. The lack of ES teacher training at the university reveals the necessity for a strong in-service and a revision of university teachers' courses.

Session Summary IIIA: Research and evaluation studies of instructional innovations

Summary prepared by Rosanne W. Fortner using notes from the discussion leaders: Fortner, Alfredo Bezzi and Roger Trend.

The guiding thought for this theme was that we are really just beginning our research on systems learning, and the primary goal is to help people overcome cognitive obstacles. Several subthemes emerged from the discussion groups in this session:

- the importance of research to inform practice,
- an analysis of the research tools we are (should be) using,
- preparing personnel for the various levels of education, from classroom teacher to teacher educator to researcher, and
- cultural implications of geoscience education research.

RESEARCH INTO PRACTICE.

Participants in the session voiced concern that it is very difficult to assess whether students (and teachers) have a systems level of thinking. As yet few researchers are comfortable with the possibility that understanding, not just knowledge, might be measurable. This will be a complex process, parallel to the complexities of the systems themselves, so assessment will have to relate to several levels of cognition: knowing, using information, knowing what to use and when, etc.

Researchers should take care not to threaten the subjects of their research, but to involve them as participants in the learning process of research. It should be possible to establish a community for sharing among learners, teachers and researchers, because all will benefit from the results of good research.

RESEARCH TOOLS.

There was a consensus that, while objective tests are clearly inadequate, our present research tools lack sophistication and probably are not getting at the real information that would be useful as research results. It would be good to be able to conduct one-on-one case studies, but the feasibility and generalizability of that approach make the method unrealistic. While concept maps are probably a good way to analyze readiness for a systems approach, researchers would have to justify their judgment of whether a "good" map is convergent or divergent on a particular topic. (Participants did see value in using concept maps as research tools, but most did not yet feel adequate as an interpreter of their contents.) The repertory grid described in one poster clearly holds some potential, though it is also complex in interpretation. It should also be possible to assess system thinking through an informal interview, perhaps a conversation on a field trip with notes recorded later. This might work best with older students who are less self-conscious and more likely to speak their minds.

Some participants see potential in using new multimedia tools for research, especially by tracking student progress electronically, and assessing students' way-finding skills as they use complex information systems or remotely sensed geographic images. Some of the research from fields such as geography and information sciences may help geoscience educators conduct such research.

PREPARING PERSONNEL.

Research was reported on the characteristics of the geoscience community, and perceptions were voiced that geoscience education was not always staffed by personnel trained in the field. Quite often teachers are assigned to teach the geosciences when they have not been taught the subjects themselves, or have been taught by non-specialists. A primary target for building professional security should be the primary teachers, said many participants, and the place for such professional development should be the school environment itself, with attention to creative use of available resources and environments. Another target audience is the older established teachers who may resist change to systems approaches, those who do not see a need to fix their own approach because there is nothing wrong with it. In any case, geoscientists in higher education should be setting the example for education in the future, because people teach as they have been taught. We must enact good teaching to model it.

CULTURAL IMPLICATIONS OF RESEARCH.

Two types of culture were discussed: international and multi-ethnic culture, and the culture of the teaching profession with its resistance to change. The latter received more attention in terms of sharing of mutual experiences, as indicated in the previous categories of the discussion. As for international culture, many felt the role of this forum (the conference) could be extended through different mechanisms to encourage more geoscience education research, perhaps through international collaboration, comparison of techniques across cultures, development of cooperative manuscripts, shared research by internet, and the like. The conference coordinators are excited with this possibility and hope the outcomes of the experience will include greater amounts of international research cooperation.

Session IIIB: Public Information through Museums and Other Informal Education Entities

Art Sussman and Wei Wen, Moderators

Libraries, museum programs and exhibits, stage shows and professional organization outreach can be valuable means of extending learning about Earth systems beyond what classrooms and formal media can accomplish. Examples in this poster set focused on the need for greater public awareness of Earth, including environmental stewardship aspects and the opportunity to link Earth subsystems through studies of environmental issues. Presenters from five countries described how their nonformal education efforts are designed and received by their special audiences. Outcomes from such education extend beyond test scores, resulting in sustainable development, effective resources management, and personal actions that show responsibility for protecting the environment.

Geoscience Literature and Libraries as Components of Earth System Education.

John Kawula, Pacific Lutheran University, Tacoma, WA 98447-0013 USA.

Libraries are important components of geoscience education. Due to shifting patterns of publication and budgetary pressures, libraries are focusing less on comprehensive collection development and more on selective collections, smooth integration of printed and electronic sources, and interlibrary loan. There is a concern within the library field that many minor but important forms of literature such as historical treatises, hand drawn illustrations, plates, theses, maps, GIS products and internet data files will not be preserved, indexed, used, or cited effectively. Continued recognition and use of all forms of literature is important for the full expression of the fields and the type of synthesis implied by earth systems integration. Specialized preservation and indexing projects, encouraged and/or financed by major subject fields, help ensure that this takes place.

It is also helpful for students at various levels to see and use a broad spectrum of resources. Recognition and significance of patterns such as governmental vs. private publication, textual vs. graphic, or mainstream vs. "gray" literature then become more apparent. The synthesis of concepts and ideas are often expressed most clearly in secondary or tertiary literature such as subject oriented encyclopedias. Unfortunately, these are often neglected by instructors and students who prefer to rely solely on journal or internet resources. Effective use and integration recognizes not only the full range of resource material, but the strengths and weaknesses of various indexing systems, and the availability of modern library services such as bibliographic instruction, interlibrary loan, and on-line document delivery.

Earth Science Expanded to the Universe: A New Exhibit Hall.

JoAnn Coburn, J.T. Hannibal, and P.C. Clifford, Jr., The Cleveland Museum of Natural History, 1 Wade Oval Drive, University Circle, Cleveland, OH 44106-1767 USA.

The Cleveland Museum of Natural History will open a new hall of Earth and planetary exploration this fall, integrating the disciplines of geology and astronomy in order to increase visitor knowledge and understanding of the Earth and how it works, and its place within the solar system and universe. The integrated planetary approach to geoscience will expand the concept of learning about Earth as a system to an even wider arena. Visitors to the hall will be immersed in the atmosphere of earth phenomena—walking though a lava tube, experiencing a simulated earthquake, visiting a mine and a cave. Numerous activity stations throughout the hall, from simple flip charts to interactive videos, will challenge visitors to explore Earth science in ways that demonstrate the complexities of the Earth and their relevance to everyday life.

A variety of means will be used to tease out the various strands of complex earth systems and make them more apparent to the visitor. Thematic activity guides will deal with strands such as time, life and water, for example. Classes (K through college) and self-guided program tours are being developed along with teacher guides, workshops and traveling kits for schools. Learning services for the public will be supplemented by audio tours, braille signage, hands-on carts and docent tours and demonstrations. Funding of the project includes major grants from the Reinberger Foundation and the National Science Foundation.

Getting Down to Earth: Linking Museums, Museum Earth Scientists, Professional Organizations, and the Public.

David M Rudkin, Department of Palaeobiology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, CANADA M5S 2C6.

Natural history museums are among the most effective links between Earth science and the general public. For many people, their first and often only exposure to rocks, minerals, fossils, the concept of geological time, and Earth processes in a learning context, is through the medium of a museum gallery or exhibit. Partly in response to growing visitor sophistication and expectation, traditional static systematic displays in larger museums are gradually giving way to more innovative designs. While these retain the essential museum ingredient of real specimens, the tendency now is to provide the visitor with a more conceptually-oriented experience and greater personal involvement. A related trend in public programming increasingly brings museum Earth scientists out from behind the scenes and into immediate contact with visitors, through lecture series, courses, identification clinics, and other avenues for interaction. These developments provide marvelous opportunities for enhancing baseline public literacy in the Earth sciences. While museum science specialists may communicate with the general lay public only on an occasional basis, they often maintain far more frequent contact with a burgeoning community of amateur Earth science enthusiasts, hobbyists, and collectors. This mutually beneficial linkage with amateurs is one which also has great potential for parallel development by societies and associations representing professional Earth scientists. The Paleontology Division of the Geological Association of Canada has recently established an Affiliates Program to foster interaction between members (largely professionals at universities, major museums, geological surveys, and in industry) and amateur organizations with interests in paleontology, natural history clubs, small museums, and teachers. Affiliate members receive a copy of the Directory of Canadian Paleontologists which provides listings of specialists and members with interests in public education. They also receive the Paleontology Division newsletter containing updated research summaries, meeting schedules, publication announcements, discussions of topical issues, and an Affiliates section devoted to their own submissions. The Affiliates Program is still under development, and among other things regional coordinators hope to organize visiting lectures, volunteer work opportunities, and co-operative research efforts. As Affiliates become more involved and aware, they in turn will be able to engage in more effective local outreach. Ultimately such links between amateurs and professional organizations will result in better communication and heightened awareness of the Earth sciences within a broader sector of the general public.

AGSO's Geoscience Awareness Program.

Gary Lewis, Geoscience Education, AGSO Geoscience Awareness Unit, GPO Box 378, Canberra ACT 2601, AUSTRALIA

The Australian Geological Survey Organisation (AGSO) is part of the Commonwealth Department of Primary Industries and Energy. AGSO undertakes geological and geophysical studies to provide the geoscientific knowledge necessary for the sustainable development and effective management of Australia's mineral, petroleum and groundwater resources. Its activities also contribute to understanding natural changes in the environment and natural hazards, such as earthquakes and volcanic activity.

AGSO's Geoscience Awareness Unit provides the vital link between the Organisation and the community. It operates programs for the education sector (primary & secondary), university students, government policy advisers and the general public. The greatest successes to date have been in the education sector where a teacher training and resource development program will provide teaching materials which teachers estimate will be used with over 60% of all Australian secondary school students. Other activities include government field conferences and working to raise university student awareness of the information available through the Organisation.

The Unit's operations are self funding—the Organisation pays staffing costs (2 people) but all other costs are met through sale of products, sponsorship and grants. This mode of operation has led to creative projects which meet the needs and demands of a diverse and often isolated community.

Forces of Change.

Deborah Rothberg, National Museum of Natural History, Washington, DC USA.

FORCES OF CHANGE is an exhibition project being organized at the National Museum of Natural History at the Smithsonian Institution in Washington, D.C. It will address the geological, biological, and cultural changes that have shaped and sustained the Earth since the beginning of time. More specifically, the exhibition will show that change is a constant, demonstrate the various scales at which change takes place, provide the necessary historic and scientific information needed to make informed choices, and convey the excitement and uncertainties of learning about the Earth.

The exhibition will provide this information through a series of carefully selected case studies. By examining these complex and dynamic processes as they operate in a series of smaller systems, it is easier to understand what is happening across the globe atmospherically, geologically, and environmentally. FORCES OF CHANGE is to be a permanent installation, but the regional themes will rotate every one or two years beginning with the stories of Antarctica and the North American prairies.

- Antarctica: The relatively pristine landscape of this remote continent serves as a living laboratory for scholars around the world interested in studying the processes of past and future global change.
- The Prairies: The heartland of North America is an important ecological and nutritional resource that must be carefully studied and managed if we are to preserve its viability.

In addition to hundreds of scientific and cultural objects from the Museum's collections, the exhibit will feature murals, dioramas, a stunning light-and-sound show, computer interactives, multi-media presentations, computer link-ups to research field stations in Antarctica, and highly sophisticated scientific instruments measuring and recording atmospheric, oceanographic, and seismic data from across the world, so that museum visitors will be able to monitor the state of our planet on a daily basis.

A book published in conjunction with the exhibit will feature stunning images and thought-provoking essays by the world's leading thinkers on issues raised in the FORCES OF CHANGE exhibit. Additional corollary materials will be available in a variety of formats—videos, CD-ROMs, curriculum guides, and posters—for use in classrooms, libraries, municipal buildings, and visitor centers. Traveling versions of each regional story will be available to participating museums across the country. The FORCES OF CHANGE exhibition promises to be a "force of change" itself in shaping how we think and teach about the Earth.

Sustainable Development in China: Importance of Public Education in Environmental Earth Sciences into the 21st Century.

Wei Wen, Chinese Academy of Sciences, Institute of Geochemistry, P.O. Box 1131, Guangzhou, Wushan, P.R.CHINA 510640.

In China, rapid population growth, increased demand for dwindling resources, and environmental contamination are causing severe impairment of the ecosystem, thus threatening the living standards and very existence of the population. Proper management of population control, economization of resources, and environmental protection are urgently needed for the development of a sustainable economic environment.

Research on public education in environmental earth sciences forms a major component of the public education program for sustainable development carried out in Guangdong Province, in particular the area of the Pearl River delta, by the Guangdong Provincial Research Association of Sustainable Development. Senior and intermediate leaders of Guangdong Province are presently organizing an overall plan for sustainable development in the province. A major component of this plan is an environmental Earth sciences education program to be carried out by the Guangzhou Institute of Geochemistry of the Chinese Academy of Sciences. The poster gave examples of the efficacy of this education program within a highly stratified socioeconomic society such as China. Emphasis is placed on the need to structure education programs so that they have the greatest impact in terms of both comprehension (i.e. varying education standards of population) and enactment within the Guangdong society as a whole in order for industrial development to be in harmony with nature.

How to Use Museums in Earth Science Teaching—Geomusa as an Example.

Merethe Froyland, Norwegian Museum Authority, Ullevlsveien 11, Oslo, NORWAY 0165.

GEOMUSA (GEO=geology, MUSA=museum) is an educational program in geology made by the author in cooperation with the Norwegian National Museum of Mining History, located at the famous silver mines in Kongsberg. The target group for GEOMUSA is pupils in elementary school.

GEOMUSA has two components: a Museum part and a Mine part. In the Museum part GEOMUSA encourages pupils to research and identify the characteristics of minerals. They learn new techniques for identifying minerals and about the diversity of minerals. Quartz may have different colors and calcite different crystal forms. Pupils work in the mineral exhibition in the museum; they crush minerals and look at the cleavage of minerals, and they study different crystal forms and use the exhibition to gather information. As part of the instructional package, the Museum part uses the FOSS unit titled "Earth materials" (Encyclopedia Britannica).

The Mine part in GEOMUSA encourages pupils to use what they learned in the Earth materials and GEOMUSA in nature. It demonstrates how people in earlier times have used this knowledge to find silver in the Kongsberg area. In other words, we try to combine geology, cultural history and our daily life in this second step of GEOMUSA.

To make a program like GEOMUSA you need a large collection of minerals. Few schools have such a collection, but museums do. The goals of the project are to allow pupils to use the basic knowledge in Earth materials together with the advanced knowledge in GEOMUSA, to give the pupils some experience about what they need to do to identify minerals in nature. In other words, we want pupils to know that quartz is not only like the quartz type they experienced in the Earth materials, but many types with many colors, big and small, crystal and not crystal, etc., and what is important for identifying quartz is that quartz has a hardness of 7, has glassy luster, non-cleavage and its own crystal form. Our main goal for the GEOMUSA project is to help pupils use their geology knowledge on their own in nature.

GEOMUSA is part of a Ph.D. dissertation. Ten classes have been using Earth materials and five of them were selected to attend GEOMUSA. The pupils have done a pre-test, a second test after Earth materials, and third test after GEOMUSA. I interviewed the teachers involved and also planned to do a post-test six months after Earth materials and GEOMUSA were taught, to find out what pupils remember from the Earth materials and from GEOMUSA. The data presented in this session look good for both Earth materials and GEOMUSA. The teachers say that the pupils loved it, the tests tell me that the pupils have learned a lot, and one teacher wrote after the second test: I would like to express my enthusiasm by citing one of my most tough and negative pupils...: "thank you for what you have taught me."

The Hologlobe—An Innovative Approach to Presenting Earth Science Data.

Barbara L. Summey and Horace G. Mitchell, Scientific Visualization Studio, NASA GSFC SVS, Building 28, Room S 121, Greenbelt Road, Greenbelt, MD 200771 USA. Tom Watters, Center for Earth and Planetary Studies, National Air and Space Museum, Washington, DC USA.

Overview: The Smithsonian has recently unveiled the Hologlobe exhibit—an innovative 3-D projection system for presenting Earth Science data to the general public. The Hologlobe images were designed to provide a succinct topical presentation of a number of earth science space data sets. There are five main earth image groups used in the exhibit. The first group shows clouds and weather from space and their inter-relationship to atmospheric water vapor. The second group shows the ocean temperature changes from space and the El Nino fluctuations in water temperature in the tropical Pacific. The third group shows the Earth's crust after draining the ocean. The image then shows the position of the geological plates and their relationship to the locations of earthquakes and volcanoes. The fourth group shows the human impact on the Earth as seen in city lights, gas fires and biomass burning. The last group shows the Earth's vegetation and the location of deserts and forests. This last group ties the sequence together. Life on this planet is a function of the interaction of atmosphere, the ocean, the land, and now the impact of man.

The Hologlobe exhibit images and descriptions are available to educators as an educational resource *(http://www.si.edu/hologlobe)*. This presentation described the space data sets in more detail, the image processing procedures, and the optics for the Hologlobe Exhibit, and our future plans for the Hologlobe. We are currently setting up the Smithsonian Hologlobe for presentation of near real-time satellite data.

'Apoha the 'O'opu—Characters, Kids, and Water Quality Education in Hawai'i.

D.C. Penn, Friends of Apoha, P.O. Box 62072, Honolulu, HI 96839 USA. B. Arakawa, University of Hawai'i, J. Dewell, State of Hawai'i Department of Health, and R. Rock, City and County of Honolulu, HI USA.

The role of 'Apoha the 'O'opu as a water quality educator in Hawai'i was created through the joint efforts of the U.S. Department of Agriculture, U.S. Environmental Protection Agency, State of Hawai'i Department of Health (DOH), City & County of Honolulu Department of Public Works (DPW), and many others. 'Apoha appears in numerous educational and public service media aimed at increasing water quality awareness, interest, and involvement, with an emphasis on nonpoint source water pollution. Related materials include 'Apoha t-shirts, coloring books, videocassettes, audiocassettes, and an interactive computer game.

'Apoha is an 'o'opu nakea (*Awaous stamineus*), one of five kinds of 'o'opu that swim in Hawai'i streams, estuaries, and coastal and ocean waters. Four of these 'o'opu are endemic—they live only in Hawai'i. In streams where they spend most of their adult life, these fish need clear water, full of oxygen, that flows over natural streambeds made of boulders, cobbles, and gravel. 'O'opu is a traditional and customary native Hawai'ian food, but scientists fear that disruption and destruction of 'o'opu habitat is lowering some of their populations. In fact, the 'o'opu alamo'o (*Lentipes concolor*) was listed by the U.S. Fish and Wildlife Service in 1991 as a candidate endangered species.

'O'opu habitat and populations can be disrupted or destroyed by physical, chemical, and biological changes in our stream and ocean waters. Humans are the biggest problem for 'o'opu—we change stream channels and stream flows, put different plants and animals in streams, and pollute stream and ocean water with soil, chemicals, and many other kinds of waste. 'Apoha's role as a water quality educator is to help people recognize, understand, and respond to environmental and humanmade changes in stream, ocean, and groundwater quality.

The Oahu County Cooperative Extension Service (University of Hawai'i) recently developed Water Quality Classroom Augmentation (CAP) and Public Education Programs (PEP) featuring classroom visits and public appearances by a live, costumed 'Apoha. When federal funding for these programs expired in September 1996, a group of local educators formed Friends of 'Apoha (a State of Hawai'i domestic non-profit membership corporation) with a special mission to maintain 'Apoha's presence in Hawai'i's public schools. This effort is supported by volunteers and complemented by similar DOH and DPW programs.

The 'Apoha costume generates considerable excitement and interest among school children and public audiences. However, schoolteachers and public outreach educators crave additional water quality related learning materials, activities, and experiences that will focus energies awakened by initial 'Apoha contacts. Because they readily demonstrate cumulative effects of interacting earth systems and processes, water quality and particularly nonpoint source pollution appear to be especially appropriate topics for integrated earth system science education (and its integration with other school curricula) at all levels.

Public Literacy Outreach: Dr. Art's Environmental Medicine Show.

Art Sussman, WestEd, 730 Harrison Street, San Francisco, CA 94107 USA.

Dr. Art's Environmental Medicine Show combines exciting scientific demonstrations with audience participation. Three principles provide a simple yet powerful framework for understanding how our planet has been working for billions of years and how human actions threaten Earth's operating system. These principles provide a global perspective on the cycles of matter, flows of energy and web of life. This simple systems perspective helps people understand that Earth is a closed system for matter, an open system with respect to energy, and a tightly networked system with respect to life. In addition to its simplicity, this framework provides an easy way to understand environmental issues in terms of their impacts on the cycles of matter, the flows of energy and the web of life. Global climate change, for example, is due to alterations in the cycles of matter that interfere with the planetary flow of energy which can then impact the web of life in unpredictable ways.

Dr. Art Sussman, the show's developer and performer, is a scientist who has playfully labored the past 20 years in developing innovative methods to teach environmental and scientific concepts in ways that are meaningful, effective and fun. The Environmental Medicine Show has been presented at the Oakland Museum, the California Academy of Sciences, Sacramento State University, the Marin County Civic Center, the Sacramento Convention Center, and a variety of other locations.

Deepening the understandings introduced in the show, Dr. Sussman has created a web site and a booklet that explain the systems perspective in general and how it applies to understanding our planet. Like the show, both of these outreach materials are scientifically accurate, enjoyable and user friendly. They aim for a high school level of understanding that is also appropriate for the nonscientific citizen and for teachers of all age groups.

"Art Sussman's show is wonderfully entertaining and at the same time conveys essential ecological knowledge that must become an integral part of all education." Fritjof Capra, Ph.D., Director, Center for Ecoliteracy; author, *Tao of Physics* and *The Web of Life*. "Great fun. Art Sussman educates his audience with a bang—literally and figuratively. His entertaining and informative presentations communicate clearly to all ages and backgrounds." Stephen H. Schneider, Ph.D.; Climatologist with the National Center for Atmospheric Research; author, *Global Warming*.

Earth Science Education and Tourism.

Suck Won Choi, Kongju National University, Republic of Korea. L.A. Bukreeva, Herzen State Pedagogical University of Russia, St.Petersburg.

One of the main problems that we are facing now is the appalling lack of interest and information on the geosciences area carried by all sorts of tourism: school subjects tourism, tourism as a sport, ecological tourism, leisure tourism, etc. That happens due to the impoverishment of the geology curriculum in the school, university and public information scheme.

Geological fieldwork is at the very heart of the tourism curriculum yet it is under pressure from many sides. Consideration of safety, cost, availability to all tourists, access to land, erosion, not to mention ecological vandalism, inflicted on exposures are all making it necessary to improve our traditional conception of how fieldwork is concretely conducted.

These activities have been successful. It was shown they lead to a quicker and more efficient learning and to a higher level of motivation towards geosciences, besides preserving cultural heritage. This happens due to group informal interaction linkages between the students themselves during fieldwork practice.

Earth Science Museum: An Informal Education System for the Development of Public Literacy in Geosciences.

Afia Akhtar and Afroz Akhtar, Geological Survey of Bangladesh, 153 Pioneer Road, Segunbagicha, Dhaka 1000, Bangladesh Rajuk College, Section 6, Uttara Model Town, Dhaka 1230, BANGLADESH.

At the end of the 20th Century, realization comes all over the world that for our survival, to acquire proper geoscientific knowledge and its practical and right application to every corner and all levels of society is a must, as geoscience is involved with our lives and our societies. The whole world is now suffering from a series of some serious problems such as environmental degradation, climatic changes, waste product disposal, destructive effects from natural hazards, meagerness of earth resources, shortages of food production and so on due to overpopulation, as well as our unawareness and ignorance of the importance of geosciences.

To cope with these situations, adequate attention should be paid from the very beginning of the 21st Century to popularize the geosciences or earth sciences among the mass population of society. Because it is quite impossible for a group of geoscientists or people of corporate level only to solve such complicated issues without active cooperation from the public. But the public will not show any sort of interest to cooperate unless they some ideas about geosciences and the achievement of application of geoscientific knowledge.

The topmost priority is to help make the public literate, emphasizing the importance on geosciences. But, it is not easy to make the public literate in the field of geoscience, as it is a costly and field-oriented science to teach through the formal educational system; especially in the case of third world countries where population growth is extremely high in comparison to facilities available. In these circumstances, the easiest and cheapest educational systems have to be found through which people will get inspiration to learn geosciences and thus be motivated and conscious about themselves and their surroundings for the overall benefit of the society.

An Earth science or geoscience museum will be the best system as an informal educational setting where people of all ages and of all ages can acquire necessary knowledge about all aspects of geosciences. For such a purpose, a museum should have enough collections on geological findings such as rocks, minerals and their products for daily uses; fossils from micro to giant dinosaur; model and volumetrical picture of geological structures, showing prospective horizons of fuel mineral—oil, gas, coal; sources and purity of water; soil and soil classification indicating important soil horizons; attractive and colorful diagram/posters on solar system and on the planet—our Earth; age, origin and structure of the Earth- lithosphere, hydrosphere, atmosphere, biosphere and their interaction; origin of life both animal and plant; major division of geological time scale; local, regional and global geological map showing the major geological events; photographs on exploration activities and destructive effects of natural hazards; chart diagrams showing the sources of pollution of environmental ecosystems, and so on.

A museum can play an important part in popularizing the geosciences and enhancing social progress. The full-fledged Earth Science National Museum can also render helpful information for earth science research students. Elementary students can consolidate their ideas about what they are taught in the geosciences classes by visiting and admiring the geological specimens, photographs, model diagrams, and so on. So, to build up and to decorate the Earth science museum for such educational purposes needs wise planning and management and should have some national policy.

Session Summary IIIB: Public Information through Museums and Other Informal Education Entities.

Summary prepared by Dan Jax from notes provided by discussion leaders Art Sussman, Wei Wen, and Jax.

This session focused on some interesting questions that arose from the posters and the experiences of participants. In the time available it was not possible to answer the questions, but they should form the basis for new research and international collaboration/sharing.

- How can we motivate and reward scientists for their outreach? In some cases, how can we get better quality of outreach from the scientists?
- How is informal education supported? Can we reach large numbers of people at a reasonable cost to participants? Some possible solutions have been tried by those in attendance at this session. Many feel that if people pay for an experience, they value it, so admission fees and memberships are acceptable charges. Most also support cooperative underwriters and grants that enable institutions to secure additional displays and charge lower fees for participation.
- How can we evaluate what people get out of exhibits? Participants in informal learning typically came to the institution for something besides learning. Program developers should evaluate exhibits in both the developmental and final phases, soliciting audience feedback and using it in the process.
- What are the important misconceptions to address? How do you get people to confront their existing knowledge and misconceptions? What experiences do you provide?

Science activities can connect with cultural outreach and priorities of an institution, thus enhancing geoscience education in painless but important ways. Sharing of experiences will be valuable. For instance, England has a week-long science festival, and Australia has a program of traveling science education performers. Others among the poster presenters use great creativity and local interest techniques as well, and their techniques could be emulated by others.

Session IIIC: Innovative Activities for Teaching About Earth Processes

Leslie Gordon and Chris King, Moderators

Presenters in this session described high-interest activities for engaging K–12 students in learning about the Earth system. Samples from national (US) programs such as the Maury project, EPIcenter, and IMAGE were offered as demonstrations of how those projects combine disciplines and focus on interactions in Earth. Examples from Canada, Spain and the UK reinforced the fact that systems thinking is becoming the world model for Earth science education, providing relevant information for non-specialists as a basis for understanding and decision-making.

Paper Cores.

Brian Poelker, Midwest Central Middle School, 121 N. Church Street, Green Valley, IL 61546 USA.

Twenty-four construction paper cores of varying lengths are hung from the ceiling, evenly spaced throughout the room in a large rectangle, along with four site locations (A, B, C, D). Each core is made of selected colors of construction paper taped together to represent different rock strata. The cores can be positioned to show a variety of geological processes including tilting, folding, or faulting. Varying thicknesses of particular strata exhibit erosion. By designating the floor as sea level, the various heights of the cores display elevation differences. A scale of 1cm = 100m is used for the horizontal scale and 1cm = 10m for the vertical scale. This permits students to measure both the distance above sea level and the distance between cores. The sites can be placed in locations where they are vulnerable to volcanoes, landslides, earthquakes, subsidence or mining operations, along with a safe site. Rock and fossil samples are placed on identification tables. The rocks are placed on the same color construction paper as the core strata and the fossils are labeled with a number corresponding to their locations in the cores.

Students are presented with this problem: Your company has been hired to select the safest geological site for the building of a suburban development. The developers have purchased options on four sites. Your team of three geologists must examine the cores and make a detailed report for the developers regarding the suitability of each site and your final recommendation for the safest site. In addition, your report to the developers will include: a geological column describing the history of the entire area, a list of specific geological processes that have occurred near each site, a topographic map of the entire area to scale with site locations, and a cardboard model on the area built to scale.

A rudimentary knowledge of rocks, fossils, geological time, and topographic maps is prerequisite to student success in the project. However, much is learned through actual practice in the lab. The GSA video, *The Earth has a History*, does an excellent job of introducing students to the Law of Superposition and Law of Original Horizontality. The video packet includes a student activity reconstructing a geological history.

This Dynamic Planet: A Plate Tectonics Teaching Supplement.

Leslie Gordon and Robert I. Tilling, U.S. Geological Survey, 345 Middlefield Road, MS 919, Menlo Park, CA 94025 USA.

In 1989 the U.S. Geological Survey (USGS) published *This Dynamic Planet: a World Map of Volcanoes, Earthquakes, and Plate Tectonics*. The wall map, jointly published by the Smithsonian Institution, made its debut at the 1989 International Geological Congress in Washington, D.C. A second edition, *This Dynamic Planet: a World Map of Volcanoes, Earthquakes, Impact Craters, and Plate Tectonics*, released in 1994, included artistic changes in the presentation of the data to increase legibility of the map, added the locations of impact craters, and improved the explanatory text. In 1995 a general interest booklet called *This Dynamic Earth: The Story of Plate Tectonics* was released to accompany the map. The wall map has been exceptionally well received and widely distributed (nearly 50,000 copies). Since its release, numerous and continued requests have been received from teachers for classroom materials that expand on the map's explanatory text. The booklet partially filled the need, but additional classroom-specific activities and exercises are still needed.

We are now creating a teachers supplement to go with the existing map and booklet, to assist teachers in using the map in the classroom, and to teach plate tectonics in grades 5-12. Our aim is to develop a high-quality and focused assemblage of materials to facilitate the teaching of a unit on plate tectonics at a middle- to high-school level. The teaching package will consist of 3 inter-related components: two existing USGS outreach products on plate tectonics (*This Dynamic Planet* wall map and *This Dynamic Earth*, a general interest booklet), and the set of new supplementary classroom materials under development. The trio will be released as a package and made available to teachers at no (or very low) cost. The teaching supplement will not be generic educational materials on plate tectonics, as an abundance of such materials already exists. The project will focus on the development of materials specifically geared to the two existing USGS general interest plate tectonic publications (the map and booklet). It will include explanatory text, classroom activities, references and resources, black-line masters for reproduction, student maps, and so forth. Much of the writing, compilation, and review for the supplement will be done by teachers and scientists working together in a series of workshops. Classroom teachers and other educators are solicited to take part in this collaborative project. Travel funds may be available. We seek teachers willing to commit the time and energy to create such a publication. All contributors will be credited as authors in the final USGS publication.

PROJECT IMAGE: Investigating Materials About Global Environments.

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Satellite images have been appearing in precollege textbooks for quite a few years, basically as pretty pictures. Students did little with images to learn how these are used in scientific research. The purpose of IMAGE was to make available at a reasonable cost activities and images that could be used in the classroom by teachers to instruct an entire class of students in how images can be used in doing real scientific research. It is hoped that once students have become familiar with the types of information images can help us obtain, they would use this knowledge in further scientific study.

The activities in the manual address a variety of environmental issues, each of which is related to an Earth science concept. Since the activities are designed to be self-contained, they could be used in other courses such as ecology, environmental science, and geography. IMAGE activities were developed using guidelines from *Benchmarks* developed by the American Association for the Advancement of Science; from the National Research Council *Standards;* and *Scope, Sequence And Coordination* from the National Science Teachers Association.

Each activity uses at least one image and provides the student with the background information about the study topic and the image(s). Students use image interpretation methods and other skills to examine the images and extract information that will assist in learning science concept(s) and environmental issue(s) involved. The general objectives of IMAGE activities are to:

1. enhance curriculum through the study of environmental topics utilizing remote-sensing imagery.
2. illustrate techniques for using images to study science concepts and environmental issues.
3. provide students with basic information about remote sensing systems and what types of images they produce.

Project IMAGE was developed through a grant from the National Science Foundation. Twenty master teachers from across the United States spent two weeks for three summers at the Center for Astrophysics developing and refining the seventeen activities that appear in the manual. The activities were all field tested with students in junior high and senior high school.

The student manual is divided into three sections. The first section is background information on satellite images in general and an introductory activity with an image to see what it looks like and to start to realize what types of information can be learned from it. Activity One "Using a Satellite Image" is the manual's orientation to the basic methods used in image interpretation. The manual was designed so that everyone using activities would do this activity before doing any of the others. All other activities are based on methods found in this activity. The second section has eight activities that deal with natural phenomena such as flooding, hurricanes, and faults. In the third section are eight activities that address human impact on the environment such as deforestation, land use, and ozone depletion.

A major use of the satellite images is to see how some aspect of the environment changes over time. Images of the same area at different times can help in determining the human impact on the environment. The Activity on Amazon Deforestation has two images of the same area taken 14 years apart, which dramatically show how much forest area had been cleared away in that period of time. Images of Phoenix, Arizona, taken 12 years apart clearly show how much growth occurred in this desert area, which has many environmental ramifications. A shorter period of change over time is addressed in the activity on phytoplankton. The images show how much change there is in the amount of this basic part of the food chain from season to season.

A basic use of images is to identify natural and human features. This includes such things as airports, major highways, wetlands, faults, etc. A transparency grid is employed by the students to determine scale and area in several of the activities. Students are introduced to what land use maps are. Land use maps are very important to city planners and other people in government. For students who have an opportunity to use computers in their studies of images related to science, there are many images on the internet related to current research. Image processing programs allow images to be color enhanced and manipulated so that more information can be determined. This manual serves as an introduction to the power of images in gathering information. It is hoped that teachers and students may use images of their immediate area to further their study of their local environment.

The author feels that this project is excellent for this project to be finished now because of the current interdisciplinary concept of science and looking at the Earth as a system. Project IMAGE can be ordered from: Kendall/Hunt, 4050 Westmark Drive, Dubuque, Iowa 52002. USA.

EPIcenter.

Brenda Turner, Foley Middle School, 201-1 Keystone Drive, Richmond, KY 40475 USA.

My poster presentation highlighted a program which I participated in during the summer of 1996. This program was called EPIcenter, and concentrated on Earth Science for teachers in the Midwestern states. The program gave teachers a chance, not only to learn about new strategies of teaching students, but also to try these strategies for themselves before using them on students. This was a constructivist summer for me. We, as teachers, were put in the role of the student to see how the students would react to different situations of learning new concepts in Earth Science. This experience also gave us a chance to share ideas with other teachers and gain from each others' experiences.

We participated in many field trips to help with the hands-on learning, that is so important for our students. We were also required to produce a Total Implementation Plan of how we would use the information gained from the program in our curriculum once we returned to our classrooms. This gave us a chance to look at our existing programs and see how the EPIcenter activities could be integrated into already an existing curriculum to enhance it. We were given the opportunity to experience several ways to get the same concepts across to the students. We were exposed to ways of using technology to teach our students. These activities have enhanced the Earth Science curriculum in my classroom.

The Maury Project.

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The Maury Project was designed as an innovative program to encourage teachers to employ ocean studies to simulate learning in the fields of science, mathematics, and technology. By using selective physical principles and processes that control the marine environment, teachers will be able to instruct their students in scientific concepts that often are abstract and difficult to understand. The method for this learning experience is in a series of packets that employ hands on activities ranging from tides, waves, ocean density currents, coastal upwelling, wind-driven circulation, and measuring sea level from space. These packets are teacher guides using physical oceanography to help understand the ocean and how it operates. The ultimate goal of the project is to increase learning in the classroom, help students understand scientific principles by using concrete activities, and integrate science, math, and technology.

The Maury Project is sponsored by the American Meteorological Society and the United States Naval Academy. These institutions have developed and produced the teacher's guides and other needed materials. Oceanographers, naval personnel, college professors, educators, teachers, and meteorologists have combined efforts to ensure that the concepts are scientifically sound and that the lab activities are workable, relevant, and enjoyable. The material is offered free to any teacher or educator in workshops or conferences, and these educational guides have been distributed throughout the United States, England, and Australia. The strengths of The Maury Project are (1) instruction in oceanographic topics and issues that are current and up-to-date, (2) topics that have high student interest, (3) integrating science with mathematics and current technology (4) applicable from 5th to 12th grade, depending on the amount and depth of the material to be used, (5) user friendly with workable labs that are easily reproducible, and (6) looking at the world as an "earth system" where land, air, and ocean forces interact and connect.

Each packet is divided into four major divisions: introduction, basic understanding, activities, and informational services. The introduction is a narrative summary of background information written expressly for the teacher. For example in the "Tides" packet, the tides are defined along with a description of forces, tidal components, and effects. The second division is basic understandings where characteristics, factors, roles of different bodies, investigations and applications are explained. This section is essential for comprehension and understanding and is presented in a concise, easily digested, and in a logical way. The third division is the culmination as a lab activity, providing the application of the idea. This is the connection between words and doing, between the abstract and concrete. Included with the activity is a student evaluation. The last division lists a bibliography for additional information sources.

The Maury Project has been greeted with enthusiasm, not only from teachers, but also from students. These studies are outstanding, because they provide activities that focus on the earth as an interacting system where the ocean must be understood in relationship with the entire earth.

From Earth to Mars and Back—A Classroom Interlevel Experience on Earth and Space Geology Learning.

Francisco Anguita, Facultad de Ciencias Geológicas, Universidad Complutense, 28040 Madrid, SPAIN

An investigation in Planetary Geology carried out by a University Seminar was used to introduce a "Biology+Geology" High School class (of 14 to 16 year olds) to System Theory, Earth Dynamics, Comparative Planetology, and Problem-solving strategies in Earth and Space Sciences.

OBJECTIVES AND METHOD

Following the suggestions of the National Science Education Standards (1996), we have tried:

- to have the pupils learn in research contexts,
- to substitute research activities for (some) lab demonstrations,
- to stimulate pupils to use data for developing an explanation, instead of *getting an answer*, and
- to promote discussion of hypothesis in the classroom.

At the same time, and following the ideas contained in the Earth Systems Education document (Mayer et al., 1991), we have consistently used a systemic approach throughout the experience.

THE IDEA

A Seminar on Planetary Sciences has been working during the last years at the Geology Department, Universidad Complutense, Madrid, Spain. One of the topics treated currently was the origin of Chasma Boreale, a canyon near Mars' northern Pole. For the group, the Grímsvötn August 1996 eruption, which took place through a fissure under the Icelandic Vatnajökull glacier was illuminating: perhaps Chasma Boreale was also tectonically controlled, and a volcanic fissure eruption had melted the glacier, provoking a surge which carved the canyon. While preparing a paper on these ideas for a Planetary Sciences journal, we envisaged a teaching activity which would build on the wave of interest on Martian geology caused by ALH84001 and the missions then in progress; and of the possibility of presenting a case in which other planetary bodies helped us to understand ours.

THE EXPERIENCE

This idea was developed from February through April, 1997. The subjects were pupils of the "Biology-Geology" class 4th Course of the María Zambrano High School, at Leganés, near Madrid. Members of the Seminar (majoring in Geology and Physics) were active in helping the teachers to develop the idea, which consisted of five phases:

1. Introduction to the Solar System. Duration: 7 hours. As an introductory topic, the Solar System was studied mainly through the open discussion of questions raised by the teacher.
2. The Dynamic Earth. Duration: 14 hours. A battery of methods was used with this ample topic: Slide presentation and discussion, maps and diagrams analysis, and lab demonstrations (to show how the rocks behave when subjected to stresses).
3. The Planet Mars. Duration: 6 hours. A part of this session was filmed and broadcast by a TV station. This phase began with a lecture on the geology of Mars. Then followed the analysis by the pupils (in groups of 4 or 5, and oriented by the undergraduate students) of a selection of Mars Viking images. After brainstorming, each group defended its views until reaching a consensus. It was stressed, nevertheless, that many questions over Mars were still without an answer. Only then was introduced the Chasma Boreale problem. Again each small group brainstormed over these particular images and presented to the other its hypotheses; but the members of the Planetary Sciences Seminar did not gave theirs.

4. The Iceland geology. Duration: 3 hours. The fourth session was introduced with a slide viewing on Iceland geology, where the pupils were encouraged to show the progress they had made (during the phase 2) about the processes that shape the Earth. After that, a video on Grímsvötn eruption was shown, followed by a talk on volcanic risk. Only then was the Seminar hypothesis over Chasma Boreale proposed. It is fair to say that some of the groups reached the same conclusion independently.
5. The Earth as a planetary body. Duration: 2 hours. This session took place at the Department of Geology, Universidad Complutense. The undergraduate students hosted this session, in which a selection of different topographic and geologic maps of the Solar System were introduced, stressing the many problems yet to be answered in each of them. A video on the Solar System exploration closed the activity.

RESULTS

As we had guessed, the extra motivation of trying to harness a real scientific problem with outside collaboration provided a momentum which showed clearly in the marking: a third of the class, which had previous learning problems, overcame them, in some cases brilliantly. From the strictly scientific point of view, the level and accuracy of the discussions showed a really in-depth understanding of the machine Earth and her main subsystems, while, at the same time, considering our planet as a subsystem of the solar group. The holistic and systemic views were therefore easily integrated.

The undergraduate students, on their side, gained an interesting experience for potential teaching careers. They were also gratified by the recognition of their knowledge and helpfulness on the side of the pupils. As for the teachers, we had access to new insights which improve our capabilities to analyse (and, hopefully, improve) the present Earth Sciences curricula. And, last but not least, were enriched by our interlevel approach.

THE FUTURE, AND TWO REFLECTIONS

The Seminar on Planetary Sciences is constructing a web site to be offered to High School teachers and pupils of Spanish-speaking countries. The teaching experience described here will be incorporated, along with the researches being carried out by the Seminar. Two morals come out from this experience: one, that Science and Science Teaching should be as close as possible. Two, that an important psychological reward is waiting for the University teachers who are not only avid to know but also avid to make others (especially young people) to know.

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Picture This...Using Illustrations of Ancient and Modern Food Webs in Teaching.

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Studies in ecology and science education suggest that visual representations of trophic systems (food webs) can be powerful tools for conveying fundamental biological concepts to students at many levels. As part of a research project aimed at the establishment and documentation of guidelines for creating illustrated food webs, comparative examples from the pelagic marine realm were developed for both a modern and a Mesozoic (Late Jurassic) setting. In contrast to conventional textbook representations, in which organisms are typically portrayed as iconic outlines with little contextual information, the new illustrations utilize vibrant color and dynamic poses to depict organisms accurately and in more naturalistic settings. Trophic levels and categories are shown by color-keyed arrows and background highlights. Additional information on relative size of organisms (from microscopic phyto- and zooplankton to the largest marine vertebrates), biological classification, and consumer groupings is provided in simplified accompanying illustrations, allowing individual aspects of the complex systems to be presented separately. Integration of data from ancient trophic systems provides a subtle hook into a complex and formidable subject area, capitalizing on a universal fascination with fossils, and leads naturally to discussions of continuity and change through time. Comparisons between the modern and ancient systems can be used to point out such phenomena as shifting patterns of dominance among groups of high-level consumers in pelagic marine ecosystems (reptiles in the Late Jurassic vs mammals and fish in modern oceans), which in turn reflect larger ecological issues of extinction and radiation. The illustrations can also serve to introduce methodologies (and levels of confidence) in the restoration of individual fossil organisms, in aut[illegible] inference, and in reconstruction of trophic str[illegible] limited palaeontological evidence. The dep[illegible] anic ecosystems is a departure from many traditional textbook examples which feature terrestrial settings, and serves to emphasize the predominantly marine record of the history of life.

In essence, the use of striking imagery in various media should allow teachers to more effectively communicate a wide range of ecological and palaeoecological principles and concepts.

Developing Effective Earth Science Teaching Approaches for Non-Earth Science Specialists.

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The inclusion of a new subject area in a statutory National Curriculum (namely Earth Science in the National Curriculum of England and Wales) has afforded a unique opportunity to evaluate the impact this has had on teachers and learners. Nowhere else in the National Curriculum has a major new content area been given to educators to teach who have never been taught the subject material themselves and have been given no prior teacher education in the new content either. This has provided the opportunity of evaluating the methods considered most effective by the teachers concerned, to support their teaching of this new content area. The teachers consulted were all teaching the Earth science component of the National Science curriculum and ranged from those who were teaching this new alien material very reluctantly to those who had become converted enthusiasts.

The responses from the 138 questionnaires returned by these science teachers teaching National Curriculum Earth Science to 11–16 year old pupils indicated the following.

- The background knowledge in Earth science of the teachers teaching this material as a result of their Higher Education is very poor.
- Earth science is taught by roughly equal numbers of biology, chemistry and physics specialists, but is taught to 14–16 year old pupils by more chemistry teachers than other subject specialists.
- The teachers say their background knowledge of Earth science is generally moderate.
- Their confidence in teaching is moderate to fairly high.
- Their enjoyment is encouragingly fairly high to moderate.

Pupil interest and achievement is reported as moderate, with greater achievement than interest. Practical work, investigational work and fieldwork content of courses is very low.

Teachers have found course textbooks for 11–14 year olds and 14–16 year olds their most helpful support. They also value the help of science and geography colleagues and find popular TV programmes helpful. Specialist Earth science worksheets have been valuable as well. However, there is little use of specialist Earth science books of any sort and In Service Education and Training (INSET) has had very little impact. Teachers overwhelmingly want more help with their teaching of Earth science.

Thus, whilst most teachers say they are confident, have a reasonable background knowledge and enjoy teaching Earth science, their level of knowledge from their Higher Education, the lack of practical and field work in their courses, and the fact that they find books written at pupil level more valuable than more specialist texts all indicate a real lack of background understanding of the Earth science material. This problem is likely to be addressed most effectively by providing INSET based on specially prepared Earth science worksheets.

The Maury Project: An Education Partnership in Physical Oceanography.

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Educational partnerships are perhaps some of the most effective means for enhancing instruction. Organizations with common goals can combine their resources and talents to promote objectives that are mutually beneficial. This enables each of the partners to contribute according to their respective strengths to accomplish their desired goals.

The Maury Project is a unique partnership of the American Meteorological Society, the United States Naval Academy, the Naval Meteorology and Oceanography Command, the National Environmental Satellite, Data, and Information Service, and the National Ocean Service. These groups represent a collection of agencies involved in educational, research and operational activities of physical oceanography. Their common purpose is to promote the study of the physical foundations of oceanography in precollege schools.

The Maury Project was established in 1994. The primary activity of the program is a two-week summer workshop conducted annually at the Naval Academy in Annapolis, Maryland. In the four workshops held since 1994, 100 teachers representing all 50 states, the District of Columbia, Puerto Rico, as well as the United Kingdom and Canada, have attended. These teachers have learned about a variety of topics including: ocean instruments and data, ocean currents and tides, polar oceanography, satellite oceanography, and numerous other items pertaining to the physical processes related to the world's oceans. In addition to the workshops, several educational resource materials have been developed to assist teachers with teaching and learning about the physical foundations of oceanography. Each year, two teachers guides are produced which serve as topics for peer-training sessions conducted by Maury Project participants for their colleagues across the country. Thus far, approximately 300 peer-training sessions have brought instruction on physical oceanography to about 6000 teachers nationwide.

This partnership represents a valuable tool for promoting geoscience education. The world's oceans are a significant component of the Earth system, influencing the land masses, the atmosphere, and the biosphere. Knowledge about the physical processes of the oceans is valuable in and of itself, but also in terms of understanding the Earth system as a whole. The Maury Project provides an educational partnership which enables teachers to learn about the physical foundations of the oceans so they, in turn, can spread their knowledge to their students and colleagues alike.

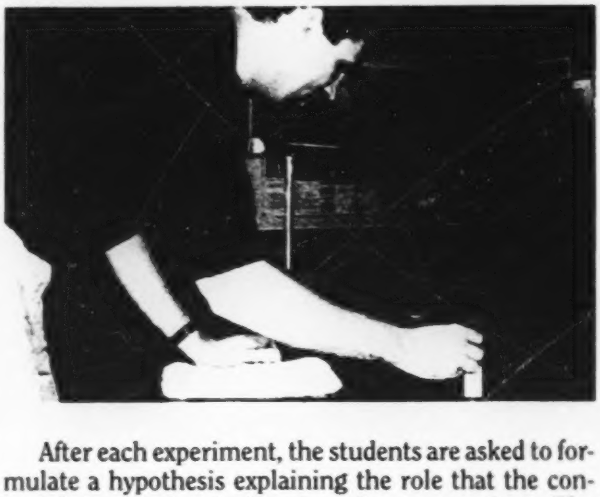
Why Do Volcanoes Erupt?

Gregory Thomas, Eastern Senior High School, 2707 Adams Mill Road, NW #101, Washington, DC 20009 USA.

What do erupting volcanoes have to do with the lives of high school students in inner-city Washington, D.C.? As it turns out, the topic of volcanoes provokes excitement, awe, and fascination in my students. Their natural curiosity about such a far away earth event reveals its dramatic proximity to their imaginations. When I ask, "What do you know about volcanoes?" they enthusiastically relate images they have seen, TV shows they have watched, and stories they have heard. Their enthusiasm for the topic is inevitably riddled with questions: "Why do volcanoes erupt? Is it true that volcanoes erupt underwater? What would happen if you were on a volcano when it erupted? In response, I make a separate list called "What we want to know about volcanoes." This sets the precedence of inquiry that drives the constructivist approach I take to teaching about volcanoes.

The guiding notion of constructivism is that you can give students information in the form of facts and concepts, but you cannot make it knowledge for them. Instead of telling students how volcanoes work, I provide a curriculum of activities that guides them to construct meaning out of science concepts and facts through first-hand experience, experimentation, and analysis.

My poster presentation showed a constructivist approach to answering the question, "Why do volcanoes erupt?" First, students in cooperative groups conduct three different experiments that simulate factors that contribute to volcanic eruptions. One group examines the role of gas pressure, using Alka-Seltzer tablets and film canisters and lids with various size holes. The second group looks at the role of viscosity by observing how gas bubbles behave differently in oil, water and corn syrup. Another group examines the role of silica by using paper clips and film canister with holes in the lids to create "magma chambers." In this experiment, students showed that the more paper clip silica chains there are, the more energy required to shake those chains out of the film canister "magma chambers."



After each experiment, the students are asked to formulate a hypothesis explaining the role that the concept being explored plays in volcanic eruptions. The poster presented examples of these student-generated hypotheses under the respective experiments. The three hypotheses lead to a single point. This represents how the students are asked to integrate their three separate hypotheses into a single unified hypothesis that attempts to explain why a volcanoes erupt. The poster showed examples of several different examples of the students' unified hypotheses.

The fourth section of the poster depicted the students creating model volcanoes to test their different hypotheses.

The Comprehension of Space by the Study of Tectonic Structures on Different Observation Scales

Celso Dal Ré Carneiro, Geosciences Institute, The State University of Campinas, Campinas BRAZIL. Alexis Rosa Nummer, Rio de Janeiro Federal Rural University, BRAZIL.

The teaching-learning of geologic processes is affected by the problem of the comprehension of space mainly on Structural Geology. These difficulties become clearer when major regional structures are studied in the field as opposed to maps, representations or lab-models studied in classroom. This paper described a series of didactic fieldtrips in a Structural Geology discipline of the Geology undergraduate course at the "Universidade Federal Rural do Rio de Janeiro." The field activities considered previous knowledge of the students and followed motivating and investigative guidelines. Students were asked to *recognize* large-scale folds in a Precambrian area. The permanent connections of theory and practice motivated the undergraduates to reach good cognitive results, excellent spatial learning, and also recovered enthusiasm of the disinterested ones.

Workshops, discussions, individual tests and workgroups were used in order to incorporate the student previous knowledge, allowing for identification of different elements: a) relationship among students; b) personal aims and perspectives; c) expectation on future professional jobs; d) previous geology knowledge; e) evaluation of geometry concepts which help to perform a space vision on natural structures; f) understanding of ways these concepts could help improving the discipline. The attitude of the teacher should be open-minded and flexible, taking into account the problems and individual characteristics of the students. Personal yield may be analyzed as a function of some specific ability and deficiency. The doubts should not be immediately answered by the teacher to stimulate a further development of the students.

Thinking and practicing science mechanism is fundamental for students as well as looking for links between natural processes and features, not as completed knowledge, but as an investigation. The approach was not exhausted. The first fieldtrip was not oriented by the teacher trying to motivate students, but this resulted in a lot of questions and low productivity, due to bad control of access conditions and also failing weather forecasting; the second excursion was initially for training in basic tools. It became investigative at the end as the students had already received basic concepts of Structural Geology. A map plotting the outcrops was required to stablish some connections among different observation scales. Students also tried to associate the observed features and local geomorphology.

The adoption of an inverse order (theory is usually presented before practical work) did not affect the results of the field activity. It really pointed out cognitive, analysis, synthesis and evaluation levels, allowing balanced participation of both students and teacher. The second fieldwork was better for a theoretical discussion on the postulates of scientific methodology. The large-scale fold and related structures were *unknown* by the teacher who selected the outcrops. So, he had identified some diagnostic characteristics of a major regional fold just before the students. Nevertheless, this *conceptual jump* apported new information which is useful for a future *inductive* activity.

Teacher Enhancement in Science Through Project QUEST: Making It Stick.

Laurel P. Goodell, Department of Geosciences, Princeton University, Princeton, NJ, 08544

Project QUEST at Princeton University is one of the largest and most established institutes for K–8 teacher enhancement in science and technology. QUEST is administered by Princeton University's Teacher Preparation Program, but privately funded. Participants receive a stipend and are provided with materials as "seeds" for their own classroom use. QUEST faculty is drawn from the University's teaching and research staff, assisted by lead teachers (themselves QUEST alumni) and undergraduates in training to be teachers. The University donates facilities, including laboratory space, classrooms, and the use of a wide variety of scientific equipment.

The core of QUEST is a 3-week summer program during which teachers are immersed in hands-on science at an unintimidating but adult level. In the geology option they explore minerals and rocks, building stones on campus, the local geology, local streams, geologic and topographic maps, and fossil collecting. They work on problems related to the data collected and complete their 3-summer program by investigating and presenting an individual research project. A full evaluation agenda includes daily comment cards from participants, daily debriefing sessions by instructors to review feedback, and pre- and post-program surveys. Teachers leave QUEST motivated by increased science confidence and knowledge.

The key to QUEST's success is in cultivating enthusiastic and effective science teaching. To keep the "sparks" created by the summer program burning long after the summer is over, teachers actively participate in a wide variety of follow activities. Most of these focus on supporting teachers in classroom applications: subgroups of QUEST participants meet to prepare a booklet of QUEST-related classroom activities; University faculty lead workshops during the school year to present supplementary topics and activities; there are opportunities to become lead teachers in subsequent QUEST sessions; formal study groups and informal support groups meet, often convened by lead teachers; the "BRIDGES" program connects teachers with Princeton undergraduates in science courses, who teach classroom science lessons in lieu of a term paper or other course requirement. Perhaps the most popular and successful follow-up activity is the spring sharing session, during which QUEST participants present a QUEST-inspired classroom activities to their fellow alumni. Teachers also obtain help from QUEST personnel on an ongoing informal basis, and are encouraged to return to QUEST for a second summer in a different subject area. The success of this multi-year, ongoing program is best testified to by those teachers, now science leaders in their schools, who got their start in Project QUEST.

Session Coordinator Summary: Innovative Activities for Teaching about Earth Processes.

Prepared by Rosanne W. Fortner from notes provided by discussion leaders: Fortner, Leslie Gordon and Chris King

For discussion groups this session was divided generally by the science content: those activities dealing primarily with geology, activities related to space, and programs that dealt with geological and oceanographic systems. The discussion leaders were developers of activities or coordinators of programs, thus they could address both the proponents' perspectives and those of the users.

Regardless of the subject matter of innovative activities, the best ones are seen to be those that are hands-on, adaptable to a range of classroom settings and/or grade levels, and engaging to students in their visual or tactile components. Many of the activities may involve other curricular areas, such as mathematics applications and writing as well as science. A good activity was described as one that allows learners to apply their existing knowledge as a framework for the assimilation of new information.

It may also be important in some settings to integrate information from textbooks or other information sources to give a complete picture of how the activity itself fits into a body of knowledge. It would not be appropriate to conduct a high-interest activity for the sake of the activity alone.

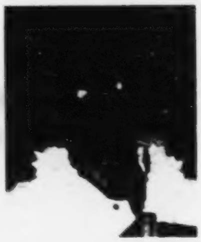
As for innovative programs, participants see a positive trend toward partnerships between government agencies and teacher education institutions, and involvement of professional societies in producing and fostering public information about such programs. The need for such innovative programs is seen as a great one. Many teachers are candidates for additional background in the geosciences, either because they were not originally trained in these areas, or they need updates on either the science or teaching techniques. Inservice programs are very helpful for meeting these needs, and can serve the K–12 teaching population in more subtle ways as well. The best inservice programs treat teachers as colleagues rather than students, and establish mutual goals for presenters and participants. Teachers can begin to see their workshop presenters as lifelong learners themselves and stakeholders in quality education.

Both the developers and the recipients of such programs were among the discussants for this conference theme, and they offered some general guidelines for such programs:

- Integration of subject matter into a systems approach is difficult, and many examples are needed so that teachers can get into the systems-thinking habit.
- College teachers should be involved as well as K-12 teachers, because "we teach as we have been taught," and lecture-based disciplinary instruction is the norm in most of higher education.
- Some college teachers consider themselves primarily researchers, and have little interest in teaching. Preservice and inservice courses should not involve those professors who are not exemplars of modern integrative, hands-on approaches.

- Innovative programs should link with preservice (teacher preparation) programs, not just inservice for existing teachers. The new generation of teachers will bring their enthusiasm into the new approaches and into their early teaching opportunities, perhaps becoming the best ambassadors of such programs. First-year teachers easily get overwhelmed, and additional support can be extremely critical.
- There should be more interface between educators and geoscientists. Discussants suggested that a position paper be developed from the educators to those scientists, inviting collaboration through a variety of opportunities.
- All new curriculum materials and programs should be field tested before publication and implementation.
- Follow-up is needed after inservice programs, so their impact will not end when the workshop is over. Suggested forms of follow-up include networking, reunions at conferences, electronic mail, continued seminars and other learning opportunities.
- Whenever possible, stipends for teacher participation should be offered for workshops during nonwork hours (weekends, summer, etc).
- Grade levels within a workshop are always a question for program providers, and decisions about this question should be based on workshop goals. While many programs are grade-level specific, there are advantages to mixing grade levels for learning about each other's work, articulating subject matter, and sharing experiences between new and seasoned teachers.

Awards for Lifetime Service to Geoscience Education



Introductory remarks by Nir Orion: On Monday evening, in the enlightened presentation given by Kepa Maly, we learned that the local term for elder is a "spring of water." Today we gather here to pay our respects and to express our gratitudes to four "springs of water." These are the founders of our growing community who have held high the light of science education in their countries for many years, some of them almost alone. Unfortunately, two of them, Professor Yolanda Gonzales from Venezuela and Professor Emmanuel Mazor from Israel, couldn't come to this conference, although they really wanted to. On behalf of all the participants here, we send our best wishes to them.

We have asked a student or a colleague of each awardee to describe the reasons for the organizing committee decision of honoring them with a lifetime service award.

Yolanda Alba de Gonzales: Introduced by Judith Riestra

Riestra

Yolanda got her degree in 1957 as Teacher of Biology and Chemistry from the Pedagogical Institute of Caracas. From the beginning of her professional activity she taught Mineralogy and Geology, a subject in the last year of Secondary School. She taught in the most important Secondary Schools in Caracas and later on she started to teach at the Pedagogical Institute of Caracas (IPC). From this new position she had the initiative to modernize the teaching of Geology and these actions ended in a Commission to create the career of Earth Science in 1971. She was the head of this Commission. Parallel to the work in this Commission she participated in a team with the aim to develop the Earth Science curriculum for secondary schools that was implemented in 1972.

The beginning of the Earth Science Department at the Pedagogical Institute of Caracas in 1972 was a very important event for the development of ES in Venezuela. This Department had an initial financial support from OEA (American States Organization) and Dr. Victor Mayer from The Ohio State University was the consultant. Yolanda was part of the teacher team in this department from 1972 until 1975 when CENAMEC called her to organize the ES Area. There she founded and consolidated a team that addressed its efforts to attend the needs of Teachers with the Earth Science curriculum that was implemented nationally in 1972 in substitution of the Mineralogy and Geology subject. This team with Yolanda at its head, developed workshops for teachers with an interdisciplinary and environmental approach in which the contents of ES were organized around an environmental problem; the workshops also had field and laboratory activities. These workshops were given to teachers all over the country during three years. Later on, Yolanda developed instructional materials for students where the basis of the instructional designs were made by secondary school teachers trained for this purpose. Among the materials were environmental situations like the Use of Soil for Agriculture, Mining and Urbanization. The first of these materials was approved by the Ministry of Education to be used in five states instead of the national curriculum. She was in charge of the Earth Science's group at CENAMEC from 1975 until 1983 when she was elected to be the Head of Earth Science Department at the Pedagogical Institute of

Caracas. There, she had the opportunity to consolidate two lines of action: 1) establish a strong inter institutional relationship with the Ministry of Environment and 2) reorganize the curriculum for teacher training for secondary school and for basic school. She retired in 1988 but continued working for the Earth Sciences being an assessor of the Earth Science Area at CENAMEC. She worked in a project aimed to produce instructional materials for students and teachers of ES at grade 7 and also materials to introduce the computer as a tool for ES teaching. In 1989 she helped with the design of a temporary curriculum for ES in secondary school. Later on in 1991 she participated in the team responsible for the new ES curriculum with an integrated, systemic and environmental approach that has been implemented in 30 schools all over the country and the next year will be extended as a national curriculum. Lately she developed audiovisual and computer materials for secondary schools, although she is not working at CENAMC at the moment. Her responsibility towards education and teacher's development have always been the objective of her professional activities. Personally, Yolanda is a very sensitive and human person with a high dedication to the development of Earth Science. Her defense of integrated science teaching and earth sciences with an integrated and environmental focus have been a permanent feature of her work.

Since Yolanda couldn't come to Hawai'i because of health problems, on her behalf I want to say to the Organizing Committe: Thank you very much for this award.

Remarks contributed by Yolanda Alba de Gonzales, Profesora Emeritus, Universidad Pedagogica Experimental Libertador, Instituto Pedagogico de Caracas, Caracas, Venezuela

I would like to thank the Co-Conveners and Arrangements Committee of the Second International Conference of Geoscience Education for the high honor bestowed on me in the name of the International Community of Earth Science Educators. I wish to specially thank my ex-student, Profesora Judith Riestra of Coordinaciòn de Ciencias de la Tierra "of the" Centro Nacional para el Mejoramiento de la Enseñanza de las Ciencias de Venezuela (CENAMEC)," for nominating me and the diligent manner in which she answered the request for documentation. And my husband Gonzalo, who gave all his support in gathering the documentation. I would especially like to thank Dr. Nir Orion, whom my colleagues Judith Riestra and Manuel Martinez informed me, offered heart felt words to those of us who could not attend the award ceremony. I specially thank my fellow countrymen; Professora Judith Riestra and Dr. Mánuel Martinez from Universidad Central de Venezuela, who came to my home following the conference to personally deliver the Plaque and Program.

It was very disappointing to me not to be able to attend the conference, especially since its theme is my passion, and also because it was a happy coincidence to be able to receive this award at the same time as Dr. Victor Mayer with whom I have had the honor of working with over 25 years ago in the project which resulted in the creation of the Earth Science Specialty at the Pedagogical Institute in Caracas.

I have now recovered from the health problems which prevented me from participating in the conference. I wish to let you know the ideas that I would have loved to express on such a special evening.

This 40 year education effort service to my country could not have been possible without the support of my family. Thus, I consider that my husband and my children, are also deserving of this award. The award which was bestowed to my person is also a recognition to the excellent training I received during the growing up process: from the family cell, to Elementary School and High School to the Chemistry and Biology Department of the National Pedagogical Institute. This would have not been possible without the contribution of the experience gathered working with Dr. Mayer, who was our Advisor on the creation of the Sciences of the Earth specialty at the Pedagogical Institute of Caracas and the learning obtained in 1972 as a participating member of the Environmental Sciences Summer Institute of the Ohio State University which he directed. Nor would its establishment have been possible if those who have come after me in the responsibilities of today's Sciences of the Earth Department of the Pedagogical of Caracas, a cell from the Libertador Experimental Pedagogical University and the Earth Sciences Coordination of CENAMEC have continued our work. It is a source of great pride that at this conference Profesora Judith Riestra is participating as one of the two graduates in this Specialty showing the high quality of our graduates.

When we began this process, we only knew that we had a mission to fulfill. Many changes have happened along the road and today it seems far away the reality of when we began this process. But, we have adapted to the changes and assumed the challenges.

The original project sponsored by the Organization of American States, in which three departments of the Pedagogical Institute of Caracas participated: Biology and Chemistry, Geography and History, and Physics and Mathematics, which satisfied a need established at International meetings by the Geology School of the Universidad Central de Venezuela, due to the deficiency in the preparation of those who during the 1960's had the responsibility of administering the courses in Mineralogy and Geology in High School Education.

It was logical, that such deficiencies exist since the National Pedagogical Institute, the only center in which teachers were prepared at that time, did not graduate professors in this specialty. Only in Biology and Chemistry is where we were legally allowed to administer the subject of Mineralogy and Geology which was one of the subjects taught in the 5th year of Physics and Mathematics and later on during the Sciences Second Diversified year. This course had a high concentration on Crystallography and Chemical Mineralogy. Professors in the specialty of Geography and History, who also had studies of Geology, taught all the courses of Geography which formed part of the High School (Secondary) Education Curriculum. However, of all graduated in the specialty of Biology and Chemistry, we were few with inclinations towards teaching Mineralogy and Geology and the rest of the courses were in the hands of very diverse professionals: Geologists, Technical Geologists, Technical Chemists, etc. Geologists from Universidad Central de Venezuela criticized the excess emphasis given to Crystallography and Chemical Mineralogy, due to the fact that more modern methods of analysis had already been developed such as X-ray spectrometric and atomic absorption, which had shifted the importance of the fields of Mineralogy as methods to identify different Minerals. These courses included lectures, activities, and lab practices and at least one field trip per year, this last one is basically focused towards Petrology and Historic Geology, and with a little emphasis on Geomorphology, which had a very high concentration in Physical Geography courses.

During the 1960's, a series of curricula were developed for the learning of this Science, centered in the Science Processes, BSCS, PSSC, Chemical Studies and ESCP, to teach Biology, Chemistry, Physics and Earth Sciences.

This last one was fed from the evaluation of the prior ones, of whose experience it enriched itself and was the only interdisciplinary character, for those who at that time were working on a level of Preparing Teachers in the Biology and Chemistry Department of the Pedagogical Institute of Caracas trying to incorporate its philosophy, its focus and some Practical activities to the Geology I and II courses.

Proposals for the curricular design suggested by Dr. Mayer after 9 weeks of work in which he was in touch with institutions and professionals in relation to the Teaching of Geology in our country, represented a true revolution in the teachers formation. We broke with the Pedagogical Departmental structure, which corresponded to the Formation of a Teacher with a high Specialization Grade, as it was from its beginnings in 1936 and still continues, even though curricular changes have happened and towards new recommendations in relation to teaching practices.

The Curricular Sub-commission that I was later to coordinate, had to go through a long adjustment process of proposals to conciliate both things, and the result was the Curricular Design of the Specialty with Interdepartmental Character.

This design did not fully satisfy us, we had to sacrifice very important aspect as was the conception of Teaching Practices and the design of some courses integrated as were the Physical Sciences. However, the ideas reacted with the Teaching Practices were taken into consideration later on, as from 1980, on which date the so called N 12 Resolution was Published which established a new Teacher's Profile in accordance with the Education Law and were not tied to the Earth Sciences specialty but adopted for all specialties.

In the middle 1970's, an institution sponsored by CONICIT and the Ministry of Education, the National Center for the Improvement of Science teachers - CENAMEC—Created with an Advisory character to the Ministry of Education, played an important role in setting up Sciences of the Earth Teaching innovations. The Sciences of the Earth Coordination, begins its projects to include the environmental focus and study of cases, inspired on learning obtained during my involvement with the Summer Institute of the Ohio State University in 1972. At the same time teachers of the three departments which participated in the project, began their Masters Programs in accordance with Dr. Mayer's recommendations, they were incorporated as members of the Staff to the so called Sciences of the Earth Section. Difficulties in the Administration of some Courses drove to changes in focusing of the same and separated each time more the Curricular Design from the Initially Proposed Specialty. Teachers and Students of the Specialty did not feel comfortable and were unsure as they were not a part of a Specific Department, and began a movement which resulted in the creation of a Sciences of the Earth Department, and the same became one more within the anachronic structure of the Pedagogical Institute. The Curricular reforms that began as from 1980, to satisfy the requirement of N 12 Resolution, more in accordance with the need to form a Teacher for the basic level, and seemed more like the initial proposal for

Sciences of the Earth, but when putting together the traditional disciplines in an area, now called Natural Sciences the specialty of Earth Sciences became a Curricular Mention to Natural Sciences.

Finally, the creation of a Pedagogical University, grouping all the Pedagogical Institutes in the Country, implied a process of Curricular homologation. As the specialty only is taught up to now in the Pedagogico de Caracas, there was no possibility of homologation but at the basic courses level.

In Summary, each change in the formation of Teacher's Curricula has represented a threat to disappearing of the specialty and as a consequence the Sciences of the Earth Department. On the other hand, the CENAMEC also lost its character as Advisor to the Ministry of Education, which allowed the same to propose innovations after the same had been validated to become an on hands executor department of Government Policies, in this manner losing, in my opinion, the freedom to propose improvements without being tied to policies influenced by government changes and subject to the swing of these changes or to engagements acquired with multinational organizations. Furthermore, we must agree that similar institutions which were created in other countries, have disappeared and the CENAMEC still lives, even though its functions are quite different to those for which they were created.

The Ministry of Education has not worked well as a system in such a manner that the creation of the Specialty did not bring the necessary adjustments for the graduates which come into the work market and will let them feel their impact to the system.

Thus, in my opinion, the most effective manner is to incorporate this innovation, and it is not at least up to now, a continuous curricular design as the one which has been developed in the US or in Israel, but in a certain manner subversive media, that of the insertion of the innovation via manufacturing materials and the attention to the Teacher in Service.

Nearing the Third Millennium, sets out a great challenge, which we must assume and will only be possible, in my opinion, with a great inter-institutional effort. For example: In our country it would be necessary to join efforts with Universities, CENAMEC, Ministry of Education, CONICIT, Centers of Digital Processing of Images etc, to bring about the direction in which Education must go. For now my contribution has been to sensitize the rectorship staff of the Experimental Libertador Pedagogical University, Personnel in the Sciences of the Earth Department of the Pedagogical of Caracas and Board of Directors of the CID Foundation, of La Victoria showing this work and setting challenges. Prof. Judith Riestra's participation has been very important to the CENAMEC as well as Dr. Manuel Martinez of the Sciences of the Earth Institute in this Conference, as these Institutions have a very important part to play and a great responsibility within this transformation process. Only with everyone participating can changes be made which leaves us with the development of information technologies.

On the contrary, we will only continue to exist as a few dreamers crashing before a society that lives with its back to the future.

Victor J. Mayer: Introduction by Dan Jax

I was very honored to be asked to say a few things about Vic Mayer and why he has been selected for such a prestigious award. It would be quite easy to list all of the projects headed, awards received, offices held, students taught, science activities written, and number of international people influenced over the course of Vic's professional life. It would not do him justice, however. Instead, in the spirit of Earth Systems's Education, which was founded in a large part by Vic, I would like to give a more relevant and holistic view of why Vic deserves this award.

The story takes place through the eyes of a young graduate student beginning his studies in science education at Ohio State. Upon his arrival, Vic immediately put him to work helping to develop science activities to be used in middle school classrooms. Vic nurtured and guided this young man through his first steps as an earth science teacher. Once this new teacher left Ohio State and set out on his own, Vic did not forget him, but encouraged him to keep returning to do coursework and to be involved in a variety of projects, including the conference where the philosophy behind Earth systems education was first devised.

This young teacher continued to be involved with Earth systems because Vic offered the opportunity. Eventually, the professional life of this young teacher was profoundly changed by a return to Ohio State to pursue coursework and research that would lead to becoming a change agent in science education at the local and national levels.

I am proud to be that teacher. I am here at this conference because of Vic. I would not have anything of value to offer to other teachers if it was not for the opportunities offered to me by Vic and the guidance he has given me over the last several years.

Yet, none of this is why I think he deserves this award. He deserves this award because there are so many other teachers and university educators aound the world who have been similaraly guided and influenced by him. Vic is a voice for science education reform that is heard on national and international levels. His influence is felt through his students and students of his students and will continue well into the future. Few people have had more of an effect on science education reform, particularly in the geosciences. I am very fortunate to have Vic as my mentor and my friend.

Science for All: an Earth System View

Victor J. Mayer, Professor Emeritus, The Ohio State University, Columbus, OH 43210 USA

We have just ended a long period of conflict between nations, the Cold War. Science and science education played a central role in waging that war and those hot wars that preceded it. We are hopefully now in a time when science education has the opportunity of leading science into a new era where it can provide the knowledge to counter the devastating environmental problems that have been a by product of a century of war, and the social problems resulting from the unfettered use of technology for political and economic gain. To do this, science educators must re-examine the very nature of science and its role in social, cultural and political systems. It is my belief that such a re-examination will result in a fundamental change in science education, a change founded on the view that science is, after all, a study of the Earth System in which we all live; not the pursuit of ever more technology. We have begun such an examination.

Earth Systems Education (ESE) provides a rationale for an international pre-college science curriculum and a global definition of science literacy. It does this by using the Earth System as the organizing theme for the development of integrated science curricula at the elementary through high school levels. Children of all nations experience weather, flowing streams, rock materials as parts of their environment. They observe the beauty of sunsets, the power of storms, the tranquility of a mountain scene, a flowing river, or an autumn day. A science curriculum organized around the student's natural environment provides a common subject for study in all cultures. The science methodology provides school children with a universal method of communication and problem solving. Thus using the Earth System as the organizational focus can provide science with a crucial role among other curricular subjects in helping students achieve a global understanding and perspective.

This approach to science curriculum is based on efforts in both the science and the science education communities. The science community through a report developed by the Earth System Science Committee, representing several United States science agencies and universities, provided a unified conceptual structure of the Earth as a system of interacting subsystems. The science education community, on the other hand, emphasized the need to modernize and integrate the science curriculum and the approaches used to teach science through reports from Project 2061 of the American Association for the Advancement of Science and the National Research Councils' committee on establishing National Science Standards. The business community, represented by the Secretary's (of the Department of Labor) Commission on Achieving Necessary Skills (SCANS), is also drawn upon for support of these changes through its workplace needs as expressed in the SCANS report. This report emphasizes industry's need for workers who are able to think creatively, solve problems from a systems perspective, work cooperatively rather than competitively, and use technology effectively.

Out of these combined efforts evolved the rationale and justification for ESE. In ESE, teachers develop curricula using an "Earth Systems Framework" of seven understandings and the view that science is really a study of Earth and its environs. Basic physical, chemical and biological concepts can therefore be learned in a meaningful context, the student's habitat. Also basic to this effort is the use of modern science data gathering and representational systems, including on line and CD-ROM data bases, images, and other sources of real science data about our planet. Students confront questions and problems in groups and share their information with other students. Teachers assess student performance through a variety of authentic assessment techniques.

Awardees Victor J. Mayer and David Thompson

Elementary school programs have been developed and implemented in Alaska, Colorado and Florida; middle school programs in three districts in central Ohio and in Oregon; and high school programs in Colorado, Ohio and New York. Some 200 teachers from all parts of the United States have been involved in the Program for Leadership in Earth Systems Education funded by the National Science Foundation. They have made presentations about ESE to well over 10,000 teachers throughout the country. A resource guide has been prepared which provides these and other teachers with assistance in developing their own Earth Systems Education integrated science curricula.

From this basis of practice in the United States, implications can be drawn for the role of Earth Systems Education in providing a basis for the development of a truly global or international definition of science literacy. This admittedly philosophical approach to international science literacy is the result of over 40 years of practice in earth science education at middle school through graduate university teaching and scholarship. I am very appreciative of support from many national and international sources including most recently, the Hyogo University of Teacher Education located in Yashiro, Japan and the support of my good friend at the university, Akira Tokuyama. I just returned from eight months at the university where I was able of synthesize many ideas that had evolved over the years of my professional involvement in earth science education. This experience convinced me that education, especially science education, can have a crucial role in developing a world citizenry that will support world peace and sustainable development of its resources to the benefit of all of our people. To do this, however, a global science literacy program must focus on the subject of all science, our Earth system and its environment in space.

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Emmanuel Mazor: Introduction by Yael Kali

Professor Mazor belongs to a very rare species of scientist. Those who perceive science education as an integral and important part of their scientific work. From his first steps in the earth sciences academic field, he has invested a lot of time and energy in the popularization of earth sciences. Among his many initiatives we would like to mention a few:

- the development of the earth science section of the Open University of Israel;
- writing of many popular books about geology and hydrology;
- preparing and broadcasting in many TV and radio series in Israel;
- initiation and practical involvement in developing a national geologic park in a unique part of Israel called Mactesh Ramon; and most of all, with his scientific reputation and pioneering charismatic personality, he succeeded to crack the educational establishment with his educational hammer.

These accomplishments enabled his successor, Dr. Nir Orion, to include the geosciences into the educational system from K–12, filling these joints with curricular substance and most important to expand the joints and allow young earth science educators to flow in. Finally I would like to add that it's a great honor for me to represent Professor Mazor who was my advisor in my M.Sc. Thesis."

Professor Mazor prepared a short paper on his educational philosophy for the Conference Proceedings.

Kali

Scientific thinking in the study of nature: observations—conclusions—theory—verification

Emanuel Mazor, The F. W. Considine Professorial Chair in Hydrological Research, Department of Environmental Sciences and Energy Research, The Weizmann Institute of Science, Rehovot 76100, Israel

INTRODUCTION

Scientific theories encompass a vast array of topics and reach high levels of sophistication. The scientists discuss science with highly specialized terms of physics, chemistry, mathematics, biology or social behaviors. How can the scientific knowledge be transferred to youngsters in elementary or high school? The best we can do is to equip the students with the basic tools of scientific thinking. In the study of nature there is a well established sequence of research steps that can be summarized as observations that lead to conclusions that are woven into working hypotheses. The working hypothesis is a theory that explains, or puts together, a large number of observations in the simplest mode. A working hypothesis is sound if it can be used to make predictions that can be checked, or in other words: a working hypothesis has to include criteria to check it via new observations. The outcome of the checks can be a verification of the theory or, in the case of contradicting observations it may call for modification and rephrasing of the working hypothesis.

Unfortunately, science is often taught by presentation of theories without the observations on which they are based. This mode of teaching has several drawbacks: the lectures sound boring and detached from reality, the listeners are left passive and in a way may feel helpless—"how can I ever understand it all?" In contrast, students find interest in the process of observing, raising questions that lead to conclusions, participating in the formulation of related working hypothesis and discussing possible criteria to further check each theory. Lessons of this nature will develop a sense of familiarity to science, curiosity and alertness.

In the process of preparing lessons that will incorporate basic observations it often turns out that we do not know, or do not remember, ourselves on what are even most common theories based. For example, how many adults can cite on which observation is based the notion that the earth is not flat? How can we prove that there were Ice Ages and that glaciers once covered large parts of Europe or America? We take biologic evolution as self evident—on what type of observations is it based?

We tell our kids that the sun is huge—is it? Preparing lessons based on observations is a thorough self-educating experience that deepens our own understanding of science. It is best if we can come up with observations that the students themselves can conduct, but in other cases we can report observations made by scientists and apply them as ingredients of the methodology of scientific thinking. The following sections deal with a number of examples, taken from the geosciences.

BASIC OBSERVATIONS THAT INDICATE HOW MOUNTAINS ARE FORMED

Peasants brought one day a sack full of rock pieces with the shape of marine shells to Leonardo Da Vinci, who right away recognized these were not merely, games of nature', as was believed in his time. He went to the place in the mountains where the fossil were found. Leonardo recorded his observations and conclusions that were: (a) these were accurate casts of a specific type of marine animals, leading to the conclusion that the host rocks were once formed in the sea, (b) he put aside the possible explanation that these may be remainders of the Biblical deluge, as he observed that in that location there were three beds of the fossils separated by other rocks, i.e. one dealt with a more common process, c) he concluded that the marine rock beds were lifted when the mountains were formed.

Let us take the class to an outcrop of marine fossils (we will observe them, but leave all in place for future scientists and visitors). Give some time for individual observations, discuss the findings, leading to the conclusion that these are marine fossils. Then present the question: "Now this location is inland on the continent—what happened since the fossils were living in the sea?" Most probably several students will make a movement of raising their arms saying the land was lifted and raised above the sea and the latter retreated—a far reaching conclusion based on a 10 minute observation (though at the right and well prepared point!). This conclusion is plausible, but how can it be checked, what other observations can shed light on it? At this point of the discussion the teacher can report observations made by ocean researchers—material that accumulates on the ocean floor along with animal remains gets lithified, i.e. turned into rocks. The nature of the accumulating material changes occasionally (as a result of changes in the neighboring continents), resulting in the accumulation of a sequence of different rock layers. Now we can discuss what is the likely orientation of newly formed marine rock layers, the answer being flat and horizontal, as the sea floor is by and large flat at the scale of tens-of-kilometers. Now we are equipped to make the next field observation—are the rock beds horizontal at our mountainous location? Soon the eyes of the students will spot the bedded structure of the rocks and they will notice that the beds are tilted—as may be expected for lifted rock masses.

HOW DO WE KNOW THAT GLACIERS COVERED LARGE PORTIONS OF THE EARTH?

Charles Darwin recorded that at the entrance to their village in England there was a huge boulder of a rock type unknown in the neighborhood, an observation that riddled him since he was a young boy. During his exploration of the Andes he observed that (a) glaciers contain rock pieces that are embedded at the base of the ice mass, (b) such rock fragments are seen in moraines left behind by melting and receding glaciers, (c) the glacial debris is composed of what looks like erratic rocks - a collection of many rock types of various shapes and sizes. He concluded that the strange big boulder at the outskirt of his village was an erratic rock left there by the last glaciers.

Glacial sediments cover wide regions 'in many countries, providing ample opportunities for a field study with a class of students. Observations to be made include first of all the "erratic" nature of the rock assemblages. Comparison of the rock types with the nearest outcrops will lead to the conclusion that the glaciers traveled for tens and even hundreds of kilometers. Another observation relates to the U-shape of the valleys, that typifies glacial terrains. In special cases parallel striations on rock beds convincingly mark the passage of former glaciers.

OBSERVATIONS IN WELLS DISCLOSING THE DYNAMICS OF GROUNDWATER SYSTEMS

Groundwater is a concealed fluid, which makes its research especially challenging. We hear about a water table, recharge, drainage and other concepts. How are these known? Can observations be made underground? Let us focus on basic observations that can be readily conducted in wells from which water is not pumped at present, e.g. ancient abandoned wells or wells drilled to serve as observation wells. The observations can be done by the students themselves, or data obtained by professional hydrologists may be applied.

A rope, or a more specific measuring tool, let into a well, reveals that a well has an upper section that is dry and beneath the well is filled with water. As this observation has been repeated in many wells, it was concluded that everywhere there is an upper-most aerated zone of soil and rocks that contain air in the voids between the solid particles, and beneath is a saturated zone in which all voids in the rocks are filled with water. The observation that water can be pumped from the saturated zone can give the impression that we deal with underground lakes or rivers. That this is not the case we learn from the experimental observation that wells have to be dug or drilled and rock material is taken out from the entire depth of the well. Thus, we deal with rocks that from a certain depth on contain water in their voids. The top of the saturated zone is called the water table. The depth of the water table at each well can be measured and is the depth at which water is first encountered in the well. The water table is observed to raise during rainy seasons, indicating that water infiltrates efficiently and water is recharged through the aerated zone. The water table in non-disturbed regions is seen to drop during dry periods—indicating that the recharged groundwater flows away from the recharge location. Where does it flow to?

The shape of the water table plane in a study area can be reconstructed by measuring the attitude of the water table at each well, and comparing it to the attitude of the water table in other wells. It turns out that as a rule, the water table is slightly inclined and the inclination is always in the direction of the nearest ocean. This observation leads to the conclusion that groundwater flows laterally in the water table zone to the ocean. An additional observation is that the water table is 'in all coastal areas nearly at sea-level, leading to the conclusion that groundwater is indeed discharged to the ocean's surface. The described set of simple observations conducted on non-pumped wells sheds light on the dynamics of the groundwater system.

Are crustal plates really moving?

Continental drift and plate tectonics are parts of a most fashionable theory. How was this theory developed? On which observations is it based? How can it best be taught at school? The first stage is rather well known - Wegner, a German meteorologist, at the turn of the century turned attention to the similarity of the continental outlines on both sides of the Atlantic Ocean, and he postulated that once there was one proto-continent that was split and the parts moved away from each other, letting the ocean water flow in between. This was a very elegant combination of a simple observation made on the world map and a deduced hypothesis. The difficulty was that it was hard to suggest criteria to check the validity of the theory. The distance between the continents on both sides of the Atlantic Ocean spans around 3000 kilometers, and no one had, at the beginning of the century, any indication that parts of the earth's crust have really moved along such an enormous path. So the theory was not accepted. It gained recognition only when new observations supported it, e.g.: (a) mapping of the ocean's floor revealed that at its center there in a mid-Atlantic ridge, that has a shape that is similar to the shape of the continental margins on both sides of the ocean, (b) the ridge is built of basalt and other volcanic rocks, (c) the ridge is highest at its center and it levels off symmetrically on both sides, (d) rocks have been collected from the mid-oceanic ridge and dated, and the outcome is that the age increases as the rocks are farther away from the center of the ridge, (e) at the top of the ridge is a trench, resembling a rift valley. These basic observations lead together to the working hypothesis that the ancient super-continent fractured and the two parts indeed drifted away from each other. In parallel, magma from the mantle rose along the fracture plane, accumulating as rocks on both sides of the rift trench and the latter were carried away only to make room for new basalts that were carried away as well. The refined working hypothesis reconciled a large body of observations and hence was easier to accept. Even the rate of the spreading was calculated dividing the distance between measured rocks by their age. The outcome—about 2.5 cm/y.

Other observations can be brought to the class to elucidate the concept of continental drift and mountain building, e.g. India that—wondered 7000 kilometers to the north and collided with Asia to form the Himalaya—a great story with much to see in the atlas.

Can we reconstruct ancient landscapes, based on the rocks left behind?

The fundamental rule of geology, the present is the key to the past, can be excellently applied in the exploration of the geological record preserved in rocks. The principle is to observe formation of rocks at present and apply the conclusions to reconstruct the paleo-environment that prevailed at the time of formation of rocks encountered elsewhere. A few examples are: (a) sandstones containing fossil tree trunks reflect continental sand dunes, whereas (b) sandstone that is interbedded with layers of clay containing marine fossils was laid down in coastal plains or near off-shore, (c) gypsum and salt deposits were formed in evaporitic coastal lagoons in dry coastal lands, (d) coal seams mark ancient lush forests, (e) limestones with marine fossils evidence former sea transgressions. These series of observations and deductions are relatively easy to convey at school level, and with them projects of exploring the local geology are feasible.

Conclusions

The approach of geoscience studies based on key observations is applicable to whatever the immediate environs offer. The selected topics and respective observations may include whatever can be reached. e.g. a marsh or swamp, an oceanic coast, a volcano, a spring, a well, rock beds of various kinds, outcrops of fossils, salt or gypsum mines, and so on. Success can be concluded when the students start to come up with observations in other domains of science and whenever they ask for the observations that support a given theory.

David Thompson: Introduction by Chris King

David Thompson is a cricketer, a footballer, a meteorologist, a geologist, a teacher, a geoscience educator. Born in the back streets of Manchester, he is a product of the United Kingdom state education system - a grammar school boy. A founder student of Keele University. A meteorologist in the Royal Air Force. A teacher at North Manchester Grammar School—its first geology teacher. A founding member of the Association for the Teaching of Geology. He became an Education Lecturer at Keele University in 1971 with the brief to develop geological education within science education nationally and internationally—and to educate geology teachers. I was one of his students. I learned that I was not to be a teacher of geology but a teacher of children. I also learned that my job was not to teach geology and science but to use geology and science to develop thinking skills in pupils to prepare them for the world.

In his talk to the conference participants, David discussed the history of the development of the science curriculum in Great Britain with clues for the future of earth science education.

David Thompson and Chris King

From a Physical Geology-geography Education for a Few Aged 11–16 to an Earth-environmental Science Education for All Aged 4–16

David Thompson, Fellow of the University, Keele, Staff, UNITED KINGDOM, ST5 5BG.

This contribution aims to provide some guidelines for the future of Earth science education based on a 40 year long experience of its past and present development in a largely British setting.

The past: 1918–1989. In England, Wales and Scotland, this period encompassed geology, earth science and environmental science as separate subjects, or as part of science and geography curricula for pupils aged 5–19. Such curricula were also common to countries and continents which had inherited and not yet discarded the educational trappings of the British Empire. With hindsight the advantages of these curricula (high academic standards fieldwork, well run examinations, etc.) were outweighed by the disadvantages (an optional system, small uptake, inadequate integration with the general education of future citizens in a democracy etc.). They were often delivered by a pedagogy that was didactic and descriptive, over-concentrating on the teaching process rather than the learning process and the opportunities offered by investigatory science and geography in the local environment. There was little educational research into earth science education and work of a constructivist nature in the 1980's was not applied.

The present: 1990–1997. The author attempts to outline and reflect upon the progress (or otherwise) of the gigantic ongoing educational innovation or "experiment" of 1990 onwards in which a National Curriculum (NC) (supported by all political parties) is being implemented in England and Wales (but in a rather different way in Scotland). In the original and four subsequent versions of the NC so far, earth and environmental science topics have been specified for pupils aged 5–16 to a diminishing extent in the National Science Curriculum (NSC) (a "double" subject which is a core i.e. compulsory subject) and in geography (NCG) (an optional subject but one which is almost universally taught). Alignment with chemistry topics is a problem. In an experiment many variables are usually controlled, but in this instance the implementation of the curricula is subject to wide variations of interpretation and practice. Much of it is idiosyncratic, due to the narrowly specialist graduate scientific backgrounds of the existing science teaching force and the lesser scientific background of the geography teachers; the organisation of school departments; wide variations in the undergraduate and postgraduate initial teacher education and training progammes; the lack of a coherent national policy of in-service professional development for teachers; implementation in part by over 100 local Education Authorities, lack of financial resources etc. An attempt will be made to focus on the positive aspects of these experiences and the many innovative responses which have been provoked and promoted. On balance it is argued that the enforced changes brought about by the NC have been educationally worthwhile because of the wide-ranging discussions and adaptations which have been engendered as much as for the purposes envisaged initially by the curriculum planners.

The future. An attempt will be made to draw up guidelines which might be helpful in advancing earth-environmental science education in cultural contexts besides those of a stable western democracy. Favoring a national curriculum which provides a corporate focus and new opportunities is commended with reservations. There is then a need to create national geoscience institutions which will generate an overall policy and a visionary curriculum model which will show how earth science will enhance and integrate with traditional subjects. A key factor in achieving this is the degree to which the geoscience profession in industry and higher education recognizes that the scientific/geographical education of pupils from ages 4–19 is a matter of self-interest as well as a national and international imperative. Much will depend upon the quality of the avenues of communication which are opened and maintained by groups which have access to power and finance and spare time to instigate, underpin, encourage and further professionalise individual teachers, school departments and teacher training institutions (with their own national curriculum).The aim should be to initiate/maintain contacts and understanding across the whole of science and politics. It is not enough to win the intellectual argument for the inclusion of the earth environmental sciences in a national curriculum; countering the arguments of lobbyists for traditional dispositions, providing ideas for resources and equipment, and demonstrating good practice in pedagogy (e.g. in field and laboratory) will be frequently needed. Leadership at many levels and a well developed sense of public relations are vital; the influencing of "the powers that be" by key individuals who have been primed by the persuasive arguments of a few dedicated enthusiasts has often prized open the door to the corridors of government and decision making.

Education has now risen to the top of the political agenda in so many countries; ears may be more open to a well-conceived approach than ever before. Organise; be bold as well as cogent; be ready to take multiple setbacks in your stride; let them be the spur to greater, more subtle, even devious, efforts. Good luck; you will need and deserve every bit of it!

Other Conference Highlights

Displays. A number of the presenters and their sponsoring agencies brought materials for distribution to the participants. While few formal displays were in place, the Campus Center lobby formed a hub of activity for people to meet and learn more about the particular programs that were providing materials.

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Social Events. The conference opened with a Welcoming Reception and closed with a traditional Hawai'ian Luau. The social events highlighted Hawai'ian food, music and dance, placing the conference in the context of important cultural concepts of Hawai'i.

Participants' evaluation of the Second International Conference on Geoscience Education: Learning about the Earth as a system

A profession grows by providing its members a forum for networking, a means of analyzing needs and approaches, a testing ground for innovation, and a mechanism for input to future developments. At GeoSciEd II, the organizers brought together individuals from diverse occupations and settings, all focused on learning about the Earth. The networking that occurred fully met the professional and social potential for such a gathering, as indicated by conference impressions and statements by participants. Photographs throughout this document attest to the level of interaction and enthusiasm that were apparent at the meeting. Participants were also able to analyze new tools for teaching and learning, explore new natural environments, learn some general information to update and internationalize their science and education knowledge, and engage in interaction in the format of poster sessions and feedback.

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To collect the input of participating professionals for the design of future conferences, two kinds of evaluations were done and results reported here.

1) An all-conference evaluation form was used to collect total impressions regarding the content and activities of the meeting. These factors constitute the professional components for development of future conferences. Based on the assumption that the next conference would be in another country and a different kind of institutional setting, specific questions about the facilities and setting were considered of lesser importance, although we recognize that participant satisfaction is built upon physical comfort in addition to mental stimulation!

2) Separate forms were used to evaluate the primary conference format —interactive poster sessions. Three days of sessions were conducted in this format. Our intent was to collect the forms at least daily and preferably after each of the ½-day Theme Sessions as formative evaluation of the process and its extent of use. The forms did serve this purpose though the attention to data collection was less than anticipated.

THE SAMPLE.

About 20% of the conference participants (44) responded to the request for evaluations of the overall conference. The low return rate is attributed to the fact that the evaluation forms were not distributed in a timely manner. Most of the respondents (30) were from the United States, six were from the United Kingdom, and the rest from seven other countries. The overwhelming majority of respondents classified themselves as educators (34, including 12 secondary teachers and 11 professors, 3 museum educators and 8 others), but there were also students, geologists, and others from business and government who gave us their reviews. Two-thirds of those who completed the questionnaires were presenters at this meeting (29 of 44), and only six had attended the First International Conference in Southampton, England, in 1993.

INFORMATION SOURCES.

A list of possible sources of information was provided on the questionnaire, and multiple answers were invited. Most respondents got conference information from more than one source. Direct mailing and personal contact were the primary means by which the conference organizers reached the potential participants (22 and 21 respondents, respectively). Another ten people received their notices in a journal or newsletter, and all the other contact methods received some attention as well. Six (15% of respondents) reported using the internet site, an innovation for this meeting.

FUNDING SOURCES.

To travel to an international conference is expensive, and many participants sought funds in addition to what they were able to provide personally. On a checklist of funding sources, with multiple answers possible, 24 people reported they relied on personal funds, 27 on their home institution or government, some on grants and some on combined sources. A grant from the National Science Foundation provided partial support for most of the secondary teachers who participated.

REASON FOR PARTICIPATION.

An open question invited participants to tell, "What was your primary reason for coming to the conference?" Research indicates that when individuals participate in an educational workshop for a combination of personal and professional reasons, the person is more likely to follow up on (use and disseminate) what was gained from the program. Of the 41 respondents to the open-ended question, 3 listed only personal reasons, such as curiosity, and revitalization; 31 listed only professional reasons, including learning techniques, networking, preparing teachers, confronting issues; and 7 (17%) listed a combination of personal and professional reasons for participation. The question asked for "your primary reason" for coming to the conference; perhaps if multiple answers were specifically called for there would have been a larger number identifying both personal and professional reasons.

MEETING PARTICIPANT NEEDS.

The conference apparently met the participants' needs adequately, as respondents rated the following (0 = Inadequate, 1 = Good, 2 = Excellent):

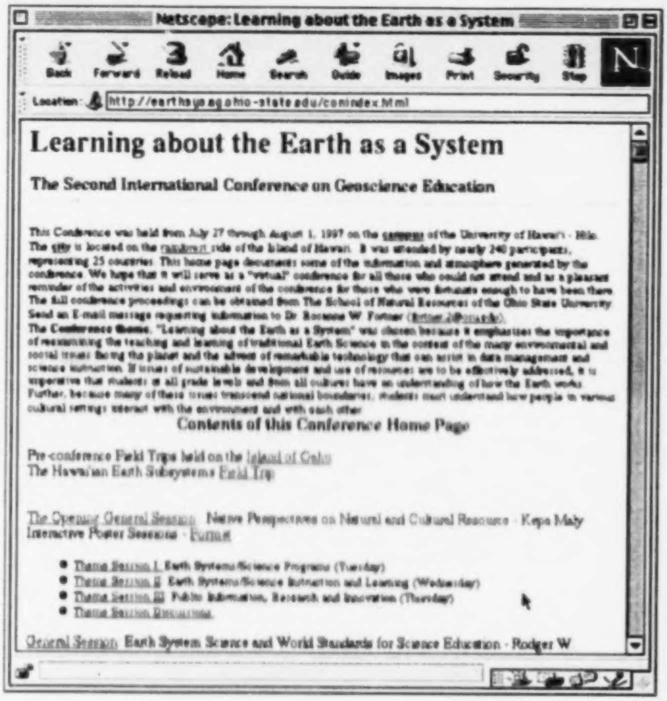
Contact with people in the field	1.5
Ideas you can use	1.3
Techniques to try	1.2
Professional growth	1.2
Geoscience knowledge gain	1.1
Learning about other cultures	1.1

Given the specified meanings of the ratings, the conference did a Good to Excellent job of meeting the set of goals listed. The results also indicate that networking was a major outcome of this meeting, and perhaps future collaborations among the participants will demonstrate further the value of such opportunities. While it is disappointing that people did not feel they learned as much about other cultures or their own discipline, the ratings are evidence that participants have emerged with new tools for teaching.

As for the format and conduct of the conference in general, participants rated major components as follows (0 = Inadequate, 1 = Good, 2 = Excellent):

All-conference trip	1.8
Pre-post activities	1.3 (30 responses)
Conference length	1.3
General session topics	1.1
Mix of formats	1.0
Advance communication	1.0

The all-conference field trip was thus the highest rated component of the conference, a combination of successful organization and enthusiastic participation of interpretive guides at the sites visited. Together with the pre- and post-activities, which included other field trips and a technology lab, these events turned out to be strong moments to encourage participants to pursue their interest in the topic of the conference.


Netscape: Learning about the Earth as a System
Back
Forward
Reload
Home
Search
Guide
Images
Print
Security
Stop
Location: http://earthsys.ag.ohio-state.edu/conindex.html

Learning about the Earth as a System

The Second International Conference on Geoscience Education

This Conference was held from July 27 through August 1, 1997 on the campus of the University of Hawai'i - Hilo. The city is located on the rainforest side of the Island of Hawaii. It was attended by nearly 240 participants, representing 25 countries. This home page documents some of the information and atmosphere generated by the conference. We hope that it will serve as a "virtual" conference for all those who could not attend and as a pleasant reminder of the activities and environment of the conference for those who were fortunate enough to have been there. The full conference proceedings can be obtained from The School of Natural Resources of the Ohio State University. Send an E-mail message requesting information to Dr. Rosanne W. Fortner (fortner.2@osu.edu).
The Conference theme, "Learning about the Earth as a System" was chosen because it emphasizes the importance of reexamining the teaching and learning of traditional Earth Science in the context of the many environmental and social issues facing the planet and the advent of remarkable technology that can assist in data management and science instruction. If issues of sustainable development and use of resources are to be effectively addressed, it is imperative that students at all grade levels and from all cultures have an understanding of how the Earth works. Further, because many of these issues transcend national boundaries, students must understand how people in various cultural settings interact with the environment and with each other.

Contents of this Conference Home Page

Pre-conference Field Trips held on the Island of Oahu
The Hawaiian Earth Subsystems Field Trip

The Opening General Session: Native Perspectives on Natural and Cultural Resource - Kepa Maly
Interactive Poster Sessions - Format

- Theme Session I: Earth Systems/Science Programs (Tuesday)
- Theme Session II: Earth Systems/Science Instruction and Learning (Wednesday)
- Theme Session III: Public Information, Research and Innovation (Thursday)
- Theme Session Discussions

General Session: Earth System Science and World Standards for Science Education - Rodger W

Participants would have been more comfortable with a greater amount of communication from the conference coordinators, and with a more traditional mixture of presentation formats, but the average rating of these was still "Good." Combining this set of responses with the previous one, it might be inferred that these responding participants would prefer general session topics and other presentation sessions related specifically to the geosciences.

INTERNET SITE.

This was the first time an internet site had been available for the Geoscience Education conference, and it was maintained on a volunteer basis by the program committee chairperson, Dr. Vic Mayer. The home page (see illustration) offered hypertext links to select for information on various components of the conference.

In this portion of the evaluation form, 17 of the 44 respondents reported accessing the home page (*http://earthsys.ag.ohio-state.edu/conindex.html*). They responded with comments that were constructive for future developers, and some of these have been implemented as appropriate in the follow-up conference web site. The participants generally appreciated knowing the program schedule in advance, and getting registration information from the site. The photographs were appreciated, as was the link to the "Virtual Tour" of Hawai'i.

According to participant suggestions, it is important for future use of a conference internet site that the site be updated regularly, have as much information as practical (precise schedule for presentations, more detailed information about field trips), and include other advance organizers such as a map of the area with hotels marked in relation to the conference site. Some participants used the internet pages for planning, but did not find all they wanted. Some participants did not know about the web site, so it is essential for organizers to inform possible participants of the resource in advance, by e-mail containing the URL, as well as hard copy forms like newsletters or journals.

The conference internet site will continue in a follow-up form as long as there is an indication that it is being used by "visitors."

CONFERENCE THEME.

"Learning about the Earth as a system" was deemed by the majority of respondents to be an excellent theme, an extremely important organizer for the new forms that science education is taking. The "systematic approach is the only way," said some, and "it ties everything together, clearly the operative paradigm for geoscience education" said others. Some comments related it to people: "an absolutely critical way for students to learn and study science." Other comments noted how well the Hawai'i conference venue supported the theme.

Those who questioned the theme were more concerned with its not being carried through into many of the presentations. Presenters tended to adhere to their disciplinary mode of operation without reference to a systems approach. Those who were new to the idea of Earth systems would have liked a more distinct definition, and appeared to be confused by the concept. Some especially were looking for how to balance depth with breadth, a common dilemma in those who are seeking to implement changes in curriculum and reconcile those with traditional teaching modes. For others, the confusion was based on their searching for systems in an orientation that would be more like engineering. They wanted to see an example of how such an integrated curriculum would look, and they suggested presentations along those lines. (A thorough review of the program abstracts will indicate that a number of opportunities were included in the program to have such interaction with curricula, especially in the workshops concurrent with and following the program.)

It was clear from the range of comments on this item that participants had given some thought to the ideas of Earth as a system, to teaching about systems, and to how this applies to their own situation. If a conference theme generates such levels of thinking, it was probably a valid goal statement and one that will be remembered!

INTERACTIVE POSTER SESSIONS.

This format of presentation was new for most people, and the reactions were mixed. Positive comments were focused on how the format was excellent for meeting people and sharing, how it was useful to select large blocks of time to focus on a single theme, and how easy it was to get the ideas of the posters from their attractive format. The positive comments included the idea that breakout sessions got better over the course of the conference, as people perceived ways to use them effectively.

One set of less positive comments focused on the groupings of the posters, with some sets not as obviously adhering to a theme as others. As one noted, "the themes seemed contrived rather than providing a focus." The program committee noted this in some cases as well, but had to organize the proposal papers submitted, around the constraint of a limited number of boards, two factors over which there could be no control. The same could be said of a concern that the presentations were too eurocentric or America-centric. No proposed paper was rejected by the committee, and every attempt was made to generate interest and support for representation from other parts of the world. Perhaps the participants in this Second conference can assist in increasing participation from the developing world for the Third conference.

Other concerns were of timing: poster presenters had little opportunity to visit others in their same session, those less fluent in English did not have enough time to absorb the information, and in general the poster review period seemed rushed. A suggestion that arose from these concerns was that posters be left up for a full day or longer, giving everyone time to see those they did not actually discuss, and allowing for better groupings to emerge for breakout sessions. One respondent wished for longer overview statements (more than three minutes), but the intent of the program committee was that these statements were to introduce and pique interest, not substitute for the poster.

Some participants were most concerned with the breakout and summary sessions. They felt these were not focused, because the posters themselves were more diverse than the theme indicated. The breadth of the themes made summaries difficult. If this format were followed in the future, perhaps an all-day display, attended by presenters for only one appointed hour, in shifts, would allow for a better grouping of topics into breakout sessions. It would also address some of the timing issues.

ADVICE FOR FUTURE CONFERENCES.

- **Site:** Suggestions from this group of respondents focused on Australia and New Zealand, with some others suggesting Iceland, Singapore and South Africa. (This conference committee strongly urges future conference developers to hold the meeting in their own geographic area. Conducting business and anticipating needs long-distance is difficult at best.)
- **Sessions and schedules:** Respondents wanted more time to tour on their own, "more informative" plenary sessions, representations of all Earth systems (including more astronomy, meteorology, oceanography), a true "Earth systems" conference, complete abstracts published in the conference program, keeping the posters up longer, retaining the breakout sessions, articulation of the theme throughout the program, greater support of the professions, and computers available in the sessions. Build in more free time to explore, and opportunities to meet each other, have more evening sessions.
- **Accommodations:** Hotels need to be closer to the conference; provide good description of facilities in advance (both housing and presenting facilities), make copiers and fax available, use shuttle transportation. In all, better information on the program and facilities in advance would have prepared participants better for the conference.
- **Evaluation procedure:** In order to get more responses, especially from participants from other countries besides the U.S., the evaluators of this conference suggest that conference organizers need to consider a new tool that could be an Internet-based survey attached to the home page of the conference. This could become part of a continuing update and communication among participants.

EPILOGUE

One of the most memorable products of this conference might be establishing interpersonal networks and a common network for the theme area, according to the participants. To maintain such networks is never easy, and the conference organizers will make every effort to encourage follow-up activities and linkages.

Major outcomes of the conference were

- confirmation of the excellence of the theme, "Learning about the Earth as a system."
- establishment of potent networks among participants.
- recognition of issues for the next conference.
- evaluation of new tools for presentation and conference organization.

Participant Addresses

[Compiled from registrations and supplied by M. Frank Watt Ireton]

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